ILLINOIS IAPC Illinois Agricultural Pesticides Conference

1990 Illinois Pest Control Handbook

Suggestions for Insect, Weed, and Plant Disease Management Including Pesticide Information

Cooperative Extension Service
University of Illinois at Urbana-Champaign
College of Agriculture

In cooperation with the
Illinois Natural History Survey

Cooperative Extension Service
University of Illinois at Urbana-Champaign

Helping You Put Knowledge to Work

The information in this handbook was prepared by specialists employed by the University of Illinois at Urbana-Champaign, College of Agriculture, the Cooperative Extension Service, the Illinois Natural History Survey, and the U.S. Fish and Wildlife Service. The suggestions herein are intended to provide guidelines for pest management in Illinois during the current calendar year only.

Because of changing laws and regulations, the Illinois Cooperative Extension Service assumes no liability for the recommendations for using pesticides that are included in this handbook. These recommendations are incomplete; therefore, they should be used only as guidelines. Complete instructions for the use of a specific pesticide are on the pesticide label. Read and follow the label directions and precautions before applying any pesticide. The pesticide user is responsible for applying pesticides according to label directions, as well as for problems that may arise through misapplication or misuse of the pesticide.

Not all pesticides registered for crop pests are included in this handbook. Effective pesticides that do not present an undue hazard to the user and the environment are suggested whenever possible. Trade names have been used for clarity, but their use does not constitute an endorsement by the University of Illinois, nor does it imply discrimination against other products.

Label changes, product cancellations, and changes in recommendations may have occurred since the publication of this handbook. Check with your county Extension adviser in agriculture if you are in doubt about a pesticide that you plan to use. Announcement of new registrations, label changes, and changes in recommendations will be made through newsletters and appropriate media sources.

Illinois Agricultural Pesticides Conference

1990 Illinois Pest Control Handbook

Suggestions for Insect, Weed, and Plant Disease Management Including Pesticide Information

Cooperative Extension Service
University of Illinois at Urbana-Champaign
College of Agriculture

In cooperation with the
Illinois Natural History Survey

Cooperative Extension Service
University of Illinois at Urbana-Champaign

Helping You Put Knowledge to Work

Acknowledgments

The compilation and publication of this handbook require considerable coordination and cooperation among several units in the College of Agriculture at the University of Illinois. Without the dedication of the individuals involved in this effort, the numerous papers and circulars it contains could never be published as a whole. Following is a list of the people responsible for the production of the *1990 Illinois Pest Control Handbook*.

Coordinator: Kevin Steffey, Extension Entomology

Section Coordinators

Insects: Kevin Steffey, Extension Entomology
Weeds: Diane Anderson, Extension Weed Science
Diseases: Walker Kirby, Extension Plant Pathology
Multiple Pests: Kevin Steffey, Extension Entomology
Equipment: Loren Bode, Extension Agricultural Engineering
Miscellaneous Topics: Phil Nixon, Extension Entomology

Office of Agricultural Communications and Education

Editorial Coordinators: Phyllis Picklesimer and Eva Kingston
Editorial Assistant: Elaine Durham
Typesetters: Oneda Huff, Virginia Cuppernell, and Nita McDonald
Designer: Jean Deichman
Conference Logo Designer: Adeline Paris

Contents

Miscellaneous

Subject Index

INSECTS

Alternatives to synthetic insecticides:

Insect pest management for:

WEEDS

Control in (site):

Control of specific weeds:

PLANT DISEASES

Plant disease management for:

MULTIPLE PESTS (insects, weeds, diseases)

PESTICIDE APPLICATION EQUIPMENT

MISCELLANEOUS

Where to Get Information

Many times throughout a growing season, you might need to contact someone for specific information that will help you make a decision related to pesticides or pest management. The following is a list of addresses and telephone numbers for people and organizations that might be able to provide some assistance.

Animal Damage Control

William R. Bonwell
Dixon Springs Agricultural Center
RR 1
Simpson, IL 62985
(618) 695-3553

Emergency Services and Disaster Agency

Oran Robinson, Hazardous Materials Officer
110 East Adams Street
Springfield, IL 62706
(217) 782-7860

Emergency Reporting
(800) 782-7860 (tollfree within Illinois)

Environmental Protection Agency, Illinois

A.G. Taylor, Agricultural Adviser
2200 Churchill Road
Springfield, IL 62706
(217) 782-3960

Emergency Response
(217) 782-3637

Hazardous Waste Research and Information Center

David L. Thomas, Director
1808 Woodfield Drive
Savoy, IL 61874
(217) 333-8940

Illinois Department of Agriculture

State Fairgrounds
P.O. Box 19281
Springfield, IL 62794-9281
(217) 782-2172

Bill Anderson, Chief
Bureau of Plant and Apiary Protection
(217) 785-2427

Warren Goetsch, Chief
Bureau of Laboratories
(217) 782-7655

Illinois Department of Public Health

Harvey Dominick, Chief
Section of Pesticides and Vector Control
Division of Environmental Health
Office of Health Protection
525 West Jefferson Street
Springfield, IL 62761
(217) 782-5830

Illinois Fertilizer and Chemical Association

Lloyd Burling, President
P.O. Box 186
St. Anne, IL 60964
(815) 427-6644

Dwight Dunbar, Vice President/Legislative Affairs
P.O. Box 357
Springfield, IL 62705
(217) 522-3734

Victor Thompson, Containment Regulations and Systems
P.O. Box 357
Springfield, IL 62705
(217) 522-3734

University of Illinois Agricultural Research and Demonstration Centers

<u>Brownstown</u>

John Sawyer, Superintendent
Route 2, Box 36A
Brownstown, IL 62418
(618) 427-5239

<u>Dixon Springs</u>

Stephen Ebelhar, Superintendent
Agronomy Division
Route 1
Simpson, IL 62985
(618) 695-2790

Illinois River Valley Sand Field

Stanley Sipp, Superintendent
Box 283
Kilbourne, IL 62655
(309) 538-4342

Northern

Lyle Paul, Superintendent
Route 1
Shabbona, IL 60550
(815) 824-2029

Northwestern

Mike Mainz, Superintendent
Route 3, Box 111
Monmouth, IL 61462
(309) 734-7459

Orr

Glenn Raines, Superintendent
Box 212
Perry, IL 62362
(217) 236-4911

University of Illinois, Cooperative Extension Service - State Offices

Agricultural Engineering

Agricultural Engineering Sciences Building
1304 West Pennsylvania Avenue
Urbana, IL 61801

Loren Bode, Pesticide Application
(217) 333-3000

John Siemens, Tillage
(217) 333-2854

Robert Wolf, Pesticide Applicator Training
(217) 333-9418

Agronomy

Turner Hall
1102 South Goodwin Avenue
Urbana, IL 61801
(217) 333-4424

Diane Anderson, Pesticide Applicator Training/Weed Science
Bill Curran, Integrated Pest Management/Weed Science
Don Graffis, Alfalfa Production
Bob Hoeft, Fertility
Ellery Knake, Weed Science
Marshal McGlamery, Weed Science
Emerson Nafziger, Crop Production and Physiology
Ted Peck, Soils
Gary Pepper, Soybean Production
David Pike, Pesticide Impact Assessment/Weed Science
Bill Simmons, Soil and Water Management

Entomology

172 Natural Resources Building
607 East Peabody Drive
Champaign, IL 61820
(217) 333-6650, 333-6651, 333-6652, or 333-6653

Mike Gray, Integrated Pest Managment/Field Crop Insects
Phil Nixon, Pesticide Applicator Training/Household and Ornamental Insects
Roscoe Randell, Turf, Ornamental, Vegetable, and Fruit Insects
Kevin Steffey, Field Crop Insects and 4-H Entomology
Rick Weinzierl, Stored Grain and Livestock Insects

Eugene Killion, Honey Bees
502 East Jasper Street
Paris, IL 61944
(217) 465-4923

Horticulture

Plant Sciences Lab
1201 South Dorner Drive
Urbana, IL 61801

Rhonda Ferree, Pesticide Applicator Training
(217) 244-0194

Tom Fermanian, Turfgrass
(217) 244-5147

Charles Voigt, Vegetable Crops
(217) 333-1969

John Masuinas, Vegetable Crops
(217) 244-4231

Dan Meador, Fruit Crops
(217) 333-1522

Tom Voigt, Turfgrass
(217) 333-7847

Dave Williams, Woody Ornamentals
(217) 333-2126

Plant Pathology

Turner Hall
1102 South Goodwin Avenue
Urbana, IL 61801
(217) 333-8375

Darin Eastburn, Vegetable Crop Diseases
Dale Edwards, Nematologist
Walker Kirby, Field Crop Diseases
Nancy Pataky, Director of Plant Clinic/Pesticide Applicator Training
Mal Shurtleff, Turf and Ornamental Diseases

University of Illinois, Cooperative Extension Service - County Offices

Adams
330 South 36th Street
Quincy, IL 62301
(217) 223-8380

Bond
Lake & Harris Avenue, Box 129
Greenville, IL 62246
(618) 664-3665

Boone
930 West Locust
Belvidere, IL 61008
(815) 544-3710

Brown
109 West North
Mt. Sterling, IL 62353
(217) 773-3013

Bureau
Route 2, Box 21B
Princeton, IL 61356
(815) 875-2878

Calhoun
Box 336 South Park Street
Hardin, IL 62047
(618) 576-2293

Carroll
Route 1, Box 5
Mt. Carroll, IL 61053
(815) 244-9444

Cass
210 South Main Street
Virginia, IL 62691
(217) 452-7255

Champaign
1715 West Springfield, Box 3367
Champaign, IL 61821
(217) 352-3312

Christian
1120 North Webster
Taylorville, IL 62568
(217) 287-7246

Clark
Route 2
Marshall, IL 62441
(217) 826-5422

Clay
231 South Main, Box F
Louisville, IL 62858
(618) 665-3328

Clinton
P.O. Box 185
Breese, IL 62230
(618) 526-4551

Coles
P.O. Box 159
Charleston, IL 61920
(217) 345-7034

Cook
4200 West Euclid Avenue
Rolling Meadows, IL 60008
(312) 991-1160

Cook
17722 South Oak Park Avenue
Tinley Park, IL 60477
(312) 532-4369

Crawford
300 South Lincoln Street, Box 655
Robinson, IL 62454
(618) 546-1549

Cumberland
Route 121 East, Box 218
Toledo, IL 62468
(217) 849-3931

DeKalb
315 North Sixth Street
DeKalb, IL 60115
(815) 758-8194

DeWitt
P.O. Box 347
Clinton, IL 61727
(217) 935-5764

Douglas
RR 2, Box 2B
Tuscola, IL 61953
(217) 253-2713

DuPage
421 North County Farm Raod
Wheaton, IL 60187
(312) 682-7486

Edgar
210 West Washington
Paris, IL 61944
(217) 465-8585

Edwards
350 North Seventh
Albion, IL 62806
(618) 445-2934

Effingham
1209 Wenthe Drive
Effingham, IL 62401
(217) 347-7773

Fayette
118 North Sixth
Vandalia, IL 62471
(618) 283-2753

Ford
100 North Hunt Street, Box 155
Melvin, IL 60952
(217) 388-7791

Franklin
P.O. Box 539
Benton, IL 62812
(618) 439-3178

Fulton
Routes 97 & 100, Box 71
Lewistown, IL 61542
(309) 547-3711

Gallatin
Murphy Street, Box 487
Ridgway, IL 62979
(618) 272-4561

Greene
RR 3, Box 129C
Carrollton, IL 62016
(217) 942-6996

Grundy
220 West Main, Suite 301, Box 432
Morris, IL 60450
(815) 942-2725

Hamilton
Courthouse
McLeansboro, IL 62859
(618) 643-3416

Hancock
550 North Madison, RR 3, Box 114A
Carthage, IL 62321
(217) 357-2150

Henderson
410 East Main, Box 540
Stronghurst, IL 61480
(309) 924-1163

Henry
116 North East Street
Cambridge, IL 61238
(309) 937-2424

Iroquois
123 South Fifth Street
Watseka, IL 60970
(815) 432-5416

Jackson
P.O. Box 160
Murphysboro, IL 62966
(618) 687-1727

Jasper
107 South Hutton Drive
Newton, IL 62448
(618) 783-2521

Jefferson
RR 3, Route 15 West
Mt. Vernon, IL 62864
(618) 242-0780

Jersey
1005 East Shipman Road
Jerseyville, IL 62052
(618) 498-4821

JoDaviess
State Bank Building, Box 1
Elizabeth, IL 61028
(815) 858-2273

Johnson
208 East Main, Box 158
Vienna, IL 62995
(618) 658-5321

Kane
535 Randall Road
St. Charles, IL 60174
(312) 584-6166

Kankakee
KCC Campus, River Road, Box 2266
Kankakee, IL 60901
(815) 939-3626

Kendall
7775B, Illinois Route 47
Yorkville, IL 60560
(312) 553-5824

Knox
180 S. Soangetaha Road, Box 1347
Galesburg, IL 61401
(309) 342-5108

Lake
33020 North Highway 45
Grayslake, IL 60030
(312) 223-8627

LaSalle
Route 23 & Dayton Road, Box 489
Ottawa, IL 61350
(815) 443-0707

Lawrence
1406 Locust Street, Box 657
Lawrenceville, IL 62439
(618) 943-5018

Lee
P.O. Box 119
Amboy, IL 61310
(815) 857-3525

Livingston
1412 South Locust
Pontiac, IL 61764
(815) 844-3622

Logan
P.O. Box 38
Lincoln, IL 62656
(217) 732-8289

Macon
985 Pershing Road, Suite G4, Box 2219
Decatur, IL 62526
(217) 877-6042

Macoupin
210 North Broad Street
Carlinville, IL 62626
(217) 854-9604

Madison
900 Hillsboro, Box 427
Edwardsville, IL 62025
(618) 656-8400

Marion
1404 East Main, Route 50 East
Salem, IL 62881
(618) 548-1446

Marshall-Putnam
300 Edward Street, Box 172
Henry, IL 61537
(309) 364-2356

Mason
133 South High, Box 170
Havana, IL 62644
(309) 543-3308

Massac
1438 West Tenth
Metropolis, IL 62960
(618) 524-2270

McDonough
3022 West Jackson Street
Macomb, IL 61455
(309) 837-3939

McHenry
789 McHenry Avenue, Box 431
Woodstock, IL 60098
(815) 338-3737

McLean
402 North Hershey Road
Bloomington, IL 61704
(309) 663-8306

Menard
420 South Seventh Street, Box 275
Petersburg, IL 62675
(217) 632-7491

Mercer
206 Southeast Third Street
Aledo, IL 61231
(309) 582-5106

Monroe
P.O. Box 117
Waterloo, IL 62298
(618) 939-3434

Montgomery
102 North Main Street, Box 370
Hillsboro, IL 62049
(217) 532-3941

Morgan
104 North Westgate Avenue
Jacksonville, IL 62650
(217) 243-7424

Moultrie
1102 West Jackson, Box 223
Sullivan, IL 61951
(217) 728-4318

Ogle
Pines Road, Box 99
Oregon, IL 61061
(815) 732-2191

Peoria
1716 North University
Peoria, IL 61604
(309) 686-6033

Perry
113 East South Street
Pinckneyville, IL 62274
(618) 357-2126

Piatt
427 West Marion, Box 407
Monticello, IL 61856
(217) 762-2191

Pike
RR 3, Box 23
Pittsfield, IL 62363
(217) 285-5543

Pope-Hardin
P.O. Box 97
Golconda, IL 62938
(618) 683-8555

Pulaski-Alexander
124 North Oak Street
Mounds, IL 62964
(618) 745-6310

Randolph
South St. Louis & Belmont, Box C
Sparta, IL 62286
(618) 443-4364

Richland
306 South Fair, Box 364
Olney, IL 62450
(618) 395-2191

Rock Island
1188 John Deere Road
East Moline, IL 61244
(309) 796-0512

Saline
21 1/2 West Robinson
Harrisburg, IL 62946
(618) 252-8391

Sangamon
P.O. Box 8467
Springfield, IL 62791
(217) 782-4617

Schuyler
710 Maple Avenue
Rushville, IL 62681
(217) 322-3381

Scott
24 South Main Street
Winchester, IL 62694
(217) 742-9572

Shelby
P.O. Box 168
Shelbyville, IL 62565
(217) 774-4321

St. Clair
116 South Charles, Box 331
Belleville, IL 62222
(618) 233-1047

Stephenson
Highland Community College
Building A, Pearl City Road
Freeport, IL 61032
(815) 235-4125

Union
RR 2, Box 305B
Anna, IL 62906
(618) 833-6363

Wabash
RR 1, Box 107
Mt. Carmel, IL 62863
(618) 262-5725

Washington
P.O. Box 192, 135B East St. Louis
Nashville, IL 62263
(618) 327-8881

White
304 East Robinson
Carmi, IL 62821
(618) 382-2276

Will
100 Manhattan Road
Joliet, IL 60433
(815) 727-9296

Winnebago
4311 West State Street
Rockford, IL 61102
(815) 987-7379

Stark
302 South Downend Street
Toulon, IL 61483
(309) 286-5421

Tazewell
1505 Valle Vista
Pekin, IL 61554
(309) 347-6614

Vermilion
3803 North Vermilion
Danville, IL 61832
(217) 442-8615

Warren
1000 North Main, Box 325
Monmouth, IL 61462
(309) 734-5161

Wayne
119 Northeast Third, Box 647
Fairfield, IL 62837
(618) 842-3702

Whiteside
100 East Knox
Morrison, IL 61270
(815) 772-4075

Williamson
906 East Reeves
Marion, IL 62959
(618) 993-3304

Woodford
P.O. Box 162
Eureka, IL 61530
(309) 467-3789

University of Illinois, Cooperative Extension Service--Regional Offices

Region 1 (Northern)

Ann Carrick, Area IPM Adviser
P.O. Box 587
Dixon, IL 61021
(815) 288-3361

Region 4 (Central)

Rob Koethe, Area IPM Adviser
P.O. Box 8167
Springfield, IL 62791
(217) 782-6515

Region 7 (Southern)

Noel Troxclair, Area IPM Adviser
901 West Washington
Benton, IL 62812
(618) 439-7263

University of Illinois Plant Clinic (Plant Problem Diagnosis)

(By U.S. Mail--Do not put "University of Illinois" on letter.)

Plant Clinic (April through September)
1401 West St. Mary's Road
Urbana, IL 61801
(217) 333-0519

1990 Insect Pest Management Guide
COMMERCIAL VEGETABLE CROPS

Restricted-use insecticides are identified with an asterisk (*).
You must be certified as a pesticide applicator to use restricted-use pesticides.
See your county Extension adviser in agriculture for information.

COMMERCIAL VEGETABLE GARDENERS find it impossible to produce vegetables profitably unless they can control insects at maximum efficiency and minimum cost. Today's cook will not accept unsightly or wormy vegetables; not only are wormy fruits and vegetables unappetizing, but the waste from trimming increases food costs. Thus the commercial grower must produce a quality product that is acceptable and safe to the consumer. Careful use of the right insecticides will make this possible.

Insect pest-management programs, which include the wise selection of cultural, mechanical, biological, and chemical methods, are suggested for the major insect pests of vegetable crops. Insecticides, though, are still the most efficient means of managing most insects.

This suggested insecticide guide has been prepared for use by Illinois commercial vegetable farmers; it is not for home gardeners, who should use only those insecticides that are extremely safe to handle, apply, and store. Furthermore, the commercial vegetable grower must use a wider variety of insecticides than the home gardener in order to obtain maximum insect control at the least cost.

In using insecticides, always read the label and carefully follow the instructions. Do not exceed maximum rates suggested; observe the interval between application and harvest, and apply the product only to crops for which use has been approved. Make a record of the product used, the trade name, the percentage content of the insecticide, the dilution, the rate of application per acre, and the dates of application.

Some of the insecticides suggested here can be poisonous to the applicator. In using them, the commercial grower is expected to use precautions to protect himself or herself, all workers, and any family members from undue or needless exposure.

In using this guide, always refer to the table on the next page, which lists the limitations and restrictions on use. These limitations apply to the vegetables as human food. If you use any portion of a vegetable for livestock food (tops, stalks, etc.), refer to product labels for instructions on the intervals required between application and feeding.

The chemical names used in these tables may be unfamiliar to you. These names are the common chemical names and as such are not capitalized. Trade names are capitalized. In the table of limitations the common names are listed first and trade names are listed in parentheses following the common name. Throughout the tables of suggestions, however, trade names are usually used. In case you have a question, refer to the table of limitations.

These suggestions are subject to change without notification during the growing season.

Check with your county Extension adviser if you are in doubt about the insecticide you plan to use. We will make announcements of label changes through newsletters and the news media to keep you up to date.

Requested label clearances for a few uses of insecticides, carriers, and solvents are uncertain for 1990, since many requests have not been officially cleared. Anticipating needed changes in labeling, we began modifying these suggested uses a few years ago.

Insecticides are being classified for *general use* or *restricted use* by the U.S. Environmental Protection Agency. Anyone who wishes to use an insecticide classified for restricted use must be certified as a private or commercial pesticide applicator by the Illinois Department of Agriculture. Contact your county Extension adviser in agriculture for details on this program.

A few insecticides have been classified at this time. More will be classified later.

Suggestions for the effective use of insecticides from a practical standpoint are based on available data. Soil textures, pH of the soil, rainfall, slope of the field, wind velocity at planting, method and accuracy of application, and other unpredictable factors affect efficiency.

Prepared by Roscoe Randell, Extension Entomologist

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
In cooperation with ILLINOIS NATURAL HISTORY SURVEY CIRCULAR 897-90 (revised annually) October 1989

LIMITATIONS FOR FIELD VEGETABLES IN DAYS BETWEEN APPLICATION AND HARVEST AND OTHER RESTRICTIONS ON USE OF INSECTICIDES IN ILLINOIS

(Blank spaces indicate that the material is not suggested for the specific use in Illinois)

Insecticide	Beans	Peas	Broccoli	Brussels sprouts	Cabbage	Cauliflower	Horseradish	Radish	Turnip	Onions	Eggplant	Peppers	Tomatoes
acephate (Orthene)	14	...	..	..	..	..	..	..	....	....	..	7	..
Bacillus thuringiensis[2]	..	...	0	0	0	0	..	..	....	....	..	..	0
carbaryl (Sevin)	0	...	3	3	3	3	3	3	3, 14F	....	0	0	0
*carbofuran (Furadan)	..	...	..	..	..	..	..	..	....	....	..	21G	..
chlorpyrifos (Lorsban)	..	...	H	H	H	H	..	H	....	H, I	..	..	..
diazinon	..	...	5	..	7	5	..	10	10	10	..	..	1
dimethoate (Cygon)	0A	0A	7	..	3	7	..	..	14	....	..	0	7
*esfenvalerate (Asana)	..	3,A,B	3C	..	3C	3C	..	..	....	....	7D	7D	1E
*fonofos (Dyfonate)	..	...	H	..	H	H	..	..	....	H, I	..	..	..
malathion	1	...	3	7	7	7	7	7	3	3	3	3	1
*methomyl (Lannate, Nudrin)	1	1, 5F	3	3	1	3	..	..	....	....	..	10	2
*mevinphos (Phosdrin)	..	...	1	3	1	3	..	..	3	....	..	..	..
*Monitor	..	...	21	21	35	28	..	..	....	....	..	..	..
naled (Dibrom)	..	...	1	1	1	1	..	..	4	....	..	..	..
*permethrin (Ambush, Pounce)	..	...	1J	1J	1J	1J	22Q	..	....	....	..	..	..
*phorate (Thimet)	C	...	..	..	..	..	..	..	....	....	..	..	..
rotenone	..	...	..	..	..	..	..	..	....	....	1	1	1
trichlorfon (Dylox)	..	...	..	21	21	21	..	..	28A	....	..	21	21

Insecticide	Potatoes	Collards	Kale	Lettuce	Spinach	Swiss chard	Sweet corn	Cucumbers[1]	Melons[1]	Pumpkins[1]	Squash[1] Winter	Squash[1] Summer
Bacillus thuringiensis[2]	..	0	0	0	0	..	..	..	..	..	..	..
carbaryl (Sevin)	0	14	14	14	14	14	0	0	0	0	0	0
*carbofuran (Furadan)	14J	..	..	..	..	..	7L,21F	H	H	H	H	H
chlorpyrifos (Lorsban)	..	..	..	..	..	..	35F, M	..	..	..	..	..
diazinon	..	10	10	10	10	12	H	7	3	..	3	7
dimethoate (Cygon)	0	14	14	14	14	14	..	..	3	..	..	..
*esfenvalerate (Asana)	7D	..	..	..	..	..	1E	3K	3K	3K	3K	3K
*fonofos (Dyfonate)	..	..	..	..	..	..	H	..	..	..	..	..
malathion	0	7	7	14	7	7	5	1	1	3	1	1
*methomyl (Lannate, Nudrin)	6	..	..	10	7	..	0 (3F)	3	3	..	..	3
*mevinphos (Phosdrin)	..	3	3	2	4	..	..	..	..	..	..	..
*Mocap	..	..	..	..	..	..	H	..	..	..	..	..
naled (Dibrom)	..	4	4	1	1	1	..	..	..	..	..	..
*permethrin (Ambush, Pounce)	7K	..	..	..	..	..	1N	..	1J	1J	..	..
*phorate (Thimet)	H	..	..	..	..	..	H	..	..	..	..	..
*terbufos (Counter)	..	..	..	..	..	..	H	..	..	..	..	..
trichlorfon (Dylox)	..	28P	21	28P	..	..	..	..	..	3Q	..	..

* Use restricted to certified applicators only.
[1] Apply insecticides late in the day after the blossoms have closed to reduce bee kill.
[2] The trade names are Bactur, Dipel, Thuricide, and Sok Bt.

REENTRY INTERVALS FOR WORKER PROTECTION

Insecticide	Days
Guthion, Dyfonate, Dibrom, Orthene, Lorsban, Thimet, Ethion	1
Lannate, Nudrin, Monitor, Parathion	2
Furadan	
(sweet corn)	14
(other crops)	1

Workers must wear protective clothing if they enter treated fields before the time intervals shown at the left. They must also wear protective clothing for all other insecticides applied if the spray has not dried or the dust has not settled.

A. Do not use tops for feed or food.
B. Do not exceed 0.1 lb a.i. per acre.
C. Do not exceed 0.4 lb a.i. acre.
D. Do not exceed 0.35 lb a.i. per acre.
E. Do not exceed 0.5 lb a.i. per acre.
F. If tops or stover are to be used for feed.
G. Not more than twice per season.
H. Soil applications at planting time only.
I. Do not use on green onion crop.
J. Not more than 8 times per season.
K. Do not exceed 0.25 lb a.i. per acre.
L. Not more than 4 applications per season.
M. Not more than once per season.
N. Not more than 6 applications per season.
P. Not after edible portions or heads begin to form.
Q. Not more than 3 times per season.

ASPARAGUS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Asparagus beetles (NHE-49)	Early and mid-season on spears and ferns	Sevin[1] malathion[1] Rotenone	1½ 1 see label directions	Spears and ferns	As needed. Spray fern growth in late summer only if beetles are present.
Cutworms (NHE-38)	Early and midseason	*Ambush, Pounce	0.01-0.02	Spears	As needed.

* Use restricted to certified applicators only.
[1] One-day restriction between last application and harvest.

BEANS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Seed maggots (NHE-27)	All season	diazinon 50% WP[1] Lorsban 25% WP[1]	3/5 oz/bu 2 oz/bu	Seed Seed	Treat seed no longer than 3 months before planting.
Bean leaf beetles (NHE-67)	Early and late season	Sevin malathion	1 1	Foliage	When feeding first appears and weekly for 2 or 3 applications as needed.
Leafhoppers (NHE-22) and Plant bugs (NHE-68)	All season	Sevin Cygon malathion *Lannate, Nudrin	1 0.3 1 0.45	Foliage	Before plants become yellow and stunted. Repeat applications at weekly intervals as necessary. Monitor leafhopper populations.
Mexican bean beetles	Midseason and late season	Sevin malathion	½ 1	Foliage	When occasional leaves show lacework feeding.
Aphids (NHE-47)	All season	Cygon malathion	0.3 1	Foliage	Usually applied when a few aphids can be found on each plant, but before leaves begin to curl and deform.
Blister beetles (NHE-72)	Midseason and late season	Sevin	1½	Foliage	As needed.
Corn earworms (NHE-33) Corn borers	Late season	Sevin Lannate, * Nudrin	1½ 0.45		As needed, but usually after August 20. Worms may be present before bloom.
Mites	Midseason and late season	Cygon	0.3	Foliage	As needed, but especially during drouth periods particularly if carbaryl has been used on crops.

* Use restricted to certified applicators only.
[1] No restrictions when used as recommended.

PEAS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Caterpillars, including loopers	June	*Lannate, Nudrin *Asana	½-1 0.025-0.05	Foliage	Prior to harvest if worms are present.
Aphids	May-June	Cygon	⅓	Foliage	If aphids are numerous.

* Use restricted to certified applicators only.

CABBAGE AND RELATED COLE CROPS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Cabbage maggots[1] (NHE-44)	All season	diazinon Dyfonate	3 2	Broadcast	Disk in just before planting. Use only for cabbage, cauliflower, and broccoli.
		diazinon G	1	Furrow	At time of planting; on turnips a drenching spray of 1 lb diazinon should be applied 30 days following treatment.
		diazinon Lorsban Lorsban	4 oz per 50 gal transplant water 3 oz 4E per 1,000 ft of row 1 oz 4E per 1,000 ft of row	Furrow	6 fl oz transplant water per plant. Transplant drench to cabbage, broccoli, and cauliflower. Radishes only.
Aphids (NHE-47) Thrips (NHE-48)	All season	Cygon *Monitor	0.3 1	Foliage	When aphids appear, but before leaves begin to curl. Control thrips when heads begin to form.
Cabbage loopers (NHE-45); diamond-back moth larvae; imported cabbage worms	All season	*Bacillus thuringiensis* *Asana *Lannate, Nudrin *Monitor *Ambush, Pounce	See rates on label 0.025-0.05 0.45-0.9 1 0.1-0.2	Foliage	When small worms first appear, and about every 5 to 7 days thereafter. Thorough spray coverage of foliage is important. Use only *B.t.* formulations if diamond-back moth resistance is present.
Cutworms	At planting	*Asana Dylox	0.025-0.05 1	Base of plants	As needed.
Flea beetles	All season	Sevin *Asana	1½ 0.025-0.05	Foliage	As needed.

NOTE: EC = Emulsion concentrate; WP = wettable powder.
* Use restricted to certified applicators only.
[1] Maggots are resistant to diazinon in some areas of Illinois.

COLLARDS, KALE, LETTUCE, SPINACH, AND SWISS CHARD

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Aphids (NHE-47)	All season	diazinon Cygon *Phosdrin Dibrom	½ 0.3 ¼ 1	Foliage	As needed.
Cutworms	On seedling plants	Dylox[1]	1	Base of plant and soil	When first damage appears.
Leafhoppers	All season	Sevin Cygon malathion	1½ 0.3 1	Foliage	When first leafhoppers appear, and as needed.
Caterpillars (NHE-45)	All season	*Bacillus thuringiensis* *Lannate, Nudrin[2] Dibrom	See rates on label 0.45 1	Foliage	When small worms first appear and every 5 to 7 days thereafter.
Leaf miners	All season	diazinon Cygon	½ 0.3	Foliage	When first miners are observed.
Flea beetles	All season	Sevin	1	Foliage	As needed.

* Use restricted to certified applicators only.
[1] Do not use on spinach or Swiss chard.
[2] Use limited to lettuce and spinach only.

CUCUMBERS AND OTHER VINE CROPS[1]

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Striped and spotted cucumber beetles (NHE-46)	Seedling to mature plants	Sevin *Furadan G	1 2	Foliage Soil	When beetles first appear; as often as necessary thereafter. Apply Furadan at planting or transplanting.
Aphids (NHE-47)	All season	diazinon Cygon[2] malathion	½ 0.3 1	Foliage	When aphids become noticeable.
Squash bugs (NHE-51)	All season	*Ambush, Pounce[4] Dylox[3]	0.2 1	Foliage	Do not appy until first eggs are found hatching (about June 15 to July 15); Dylox controls only nymphs.
Leafhoppers	July-August	*Asana Cygon[2] *Ambush, Pounce[4]	0.025-0.05 0.3 0.1-0.2	Foliage	Only needed when leafhopper populations are high.
Squash vine borers	June-September	Sevin *Asana	1 0.025-0.05	Base of stem for 3 ft	Weekly applications when vines begin to run—usually 5 applications.
Pickle worms	August-September	Sevin *Asana	1 0.025-0.05	Foliage	Weekly applications, beginning in late August. Not a common problem.
Mites	July-September	Cygon	0.3	Foliage	As needed.
Cutworms (NHE-77)	April-June	Sevin *Asana *Ambush, Pounce[4]	2 0.05 0.1-0.2	Base of plants	As needed at plant emergence or transplanting.

* Use restricted to certified applicators only.
[1] Spray vine crops with insecticide only late in the day after blossoms have closed to reduce bee kill.
[2] Do not use Cygon on cucumbers.
[3] Pumpkin is the only vine crop for which Dylox can be used for squash bug control.
[4] Pumpkin and cantaloupes only.

ONIONS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Onion maggots (NHE-50)	All season	*Dyfonate Lorsban G Lorsban EC	1 1 1	Furrow	Do not use Dyfonate or Lorsban on green onions.
		diazinon	2-4	Broadcast	Preplanting; disk into upper 1 to 2 inches of soil. Supplement with foliage spray below.
		diazinon malathion	⅓ 1	Foliage	Supplemental to soil treatment. Make first application when first adult flies are seen; make another 1 week later. From then on only as necessary.
Thrips (NHE-48)	Midseason and late season	diazinon malathion	½ 1	Foliage	When injury first appears and every 10 days as necessary.

* Use restricted to certified applicators only.

PEPPERS

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Aphids (NHE-47)	May-July	Cygon *Lannate, Nudrin Orthene	0.3 0.45 ½	Foliage	Only when aphids are present. Usually ladybird beetles and aphid lions control green peach aphids.
Corn borers	Late season	Orthene	1	Foliage and fruit	When fruit is present on plant. Apply every 5 days when borers are present.
		*Furadan	2-3	Soilband to transplant	Make 2 applications; first, 3 weeks after transplant, second, 5 weeks later.
Flea beetles	Early season	*Asana Orthene	0.025-0.05 ½	Foliage	When shiny, jumping beetles are present.

* Use restricted to certified applicators only.

POTATOES

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Colorado potato beetles; cutworms; flea beetles; potato leafhoppers (NHE-22)	May-July	Sevin *Furadan G *Furadan F Cygon *Asana *Ambush, Pounce	2 3 1 0.3 0.025-0.05 0.1	Foliage In furrow Foliage Foliage Foliage Foliage	As needed. Planting time. As needed. As needed. As needed. As needed.
		*Thimet G	2-3	Soilband	Place on either or both sides of row at planting, but not in contact with seed. Use the lower rate on sandy soils, the heavier rate on heavy soils. Do not use on muck soils.
Aphids (NHE-47)	All season	Cygon *Lannate, Nudrin	0.3 0.45	Foliage	As needed.
		*Thimet G	2-3	Soilband	Same as for leafhoppers.
Blister beetles (NHE-72)	All season	Sevin	1½	Foliage	As needed.
Wireworms (NHE-43) White grubs (NHE-23)	All season	*Thimet G *Furadan	2-3 3	Soil Soil	Preplanting, disk in; or use as soilband at planting.
Grasshoppers (NHE-74)	July-September	Sevin Cygon	¾ 0.3	Foliage	As needed, control in fencerows, roadsides, ditch banks, etc., before adult migration.

* Use restricted to certified applicators only.

HORSERADISH

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Caterpillar (diamondback moth)	July-August	*Bacillus thuringiensis* Ambush, Pounce	Follow label directions 0.1	Foliage	Apply when worms are present and feeding holes are observed.
Beet leafhopper	July-August	Ambush, Pounce Lanate, Nudrin	0.1 0.45	Foliage	Either when migrating beet leafhoppers are collected or brittle root begins to appear in fields.
Imported crucifer weevil	May-August	Ambush, Pounce	0.1% 0.2	Set dip Foliage	At planting time. When adult weevils are present.

SWEET CORN

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Corn rootworm (NHE-26)	June-July	*Counter G *Dyfonate G *Furadan G Lorsban G *Mocap G *Thimet G	1 1 1 1 1 1	Furrow Row Furrow Row Row Row	Rootworm control may be needed if the field was in corn the previous year or if a worm control program was not used the previous year.
Cutworms (NHE-38)	April-June	*Asana Lorsban 4E	0.025-0.05 1½	Base of plants Broadcast	When first damage appears.
Flea beetles (NHE-36)	April-July	Sevin[1] *Furadan G	1½ 1	Foliage Furrow	As necessary. At planting.
Japanese beetles (NHE-32)	July-September	Sevin[1]	1	Ear zone	As necessary.
First-generation corn borers	May-June	Sevin[1] *Pounce, Ambush	2 0.1-0.2	Foliage	If needed make first application in late whorl stage. Repeat in 5 to 7 days.
Second-generation corn borers	July-September	*Ambush, Pounce *Furadan[2]	0.1-0.2 0.5	Tassel Ear zone	*Processing corn:* Observe light traps for borer adults. When there are 50 or more trapped per night and 1,500 or more heat units (base 50) have accumulated, spray at row tassel and every 5 to 7 days until 10 to 12 days of harvest. *Fresh market corn:* Apply first spray at row tassel and additional corn earworm treatments will control corn borers.
Corn earworm	June-September	*Lannate Nudrin *Ambush, Pounce *Asana	0.45 0.1-0.2 0.025-0.05	Ear zone	*Fresh market corn:* Treat at first silk and every 2 to 4 days for 4 to 6 applications. *Processing corn:* Observe pheromone traps, if more than 10 moths per night, apply a borer spray during early silking period and repeat if necessary.
Sap beetles (NHE-10) Picnic beetles	July-September	Sevin[1] diazinon malathion	2 1 1	Foliage	When adults first appear in field; usually between pollen-shedding and silk-drying.
Corn leaf aphids (NHE-29)	July-September	malathion	1	Foliage	As needed to produce aphid-free ears for fresh market.
Fall armyworms	July-September	*Lannate, Nudrin	0.45	Foliage	Apply to ear zone when late-season whorl feeding is evident.

* Use restricted to certified applicators only.
[1] During pollen shed, apply Sevin as late in the day as possible (preferably after 4 p.m.) to reduce bee kill.
[2] Corn borer control only.

TOMATOES AND EGGPLANT

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Cutworms (NHE-77)	Early and midseason	Sevin *Asana Dylox	2 0.025-0.05 1	Base of plants and foliage	As needed.
Flea beetles	May-June	Sevin *Asana	2 0.025-0.05	Foliage	Apply every week as long as needed.
Aphids (NHE-47)	May-July	diazinon Cygon[1] malathion	½ 0.3 1	Foliage	As needed, but before leaves curl.

* Use restricted to certified applicators only.
[1] Use cleared only on tomatoes.

Insect	Time of attack	Insecticide	Pounds of active ingredient per acre	Placement	Timing of application
Cabbage loopers	July-September	*Bacillus thuringiensis* *Asana *Lannate, Nudrin	See rates on label 0.025-0.05 0.45-0.9	Foliage	When loopers are present.
Corn earworms Corn borers Hornworms	July-September	*Bacillus thuringiensis* Sevin *Asana *Lannate, Nudrin	See rates on label 2 0.025-0.05 0.45-0.9	Foliage	Add to weekly applications of fungicide sprays beginning at first fruit set when first small worms appear.
Mites	July-September	Cygon[1]	0.3	Foliage	As needed.
Fruit flies and picnic beetles	August-October	Sevin diazinon	2 ½	Foliage	When flies or beetles first appear.

* Use restricted to certified applicators only.
[1] Use cleared only on tomatoes.

FOR ADDITIONAL INFORMATION

You can obtain the following circulars on insect control from the Office of Agricultural Publications, University of Illinois, 69 Mumford Hall, 1301 W. Gregory Drive, Urbana, Illinois 61801.

Circular 899, *1990 Insect Pest Management Guide — Field and Forage Crops*
Circular 900, *1990 Insect Pest Management Guide — Home, Yard, and Garden*
Circular 1076, *1990 Turfgrass Pest Control*

Leaflets describing the life history, biology, and habits of some of the insects mentioned can be obtained from the offices of county Extension advisers or by writing to Entomology Extension, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820. These are indicated by an NHE number in the tables.

FOR YOUR PROTECTION

Always handle insecticides with respect. The persons most likely to suffer ill effects from insecticides are the applicator and his or her family. Accidents and careless, needless overexposure can be avoided. Here are a few easy rules that, if followed, will prevent most insecticide accidents:

1. Wear rubber gloves when handling insecticide concentrates.
2. Do not smoke while handling or using insecticides.
3. Keep your face turned to one side when opening insecticide containers.
4. Leave unused insecticides in their original containers with the labels on them.
5. Store insecticides out of reach of children, irresponsible persons, or animals — preferably in a locked cabinet.
6. Triple-rinse and bury or burn all empty insecticide containers or take them to an approved sanitary landfill.
7. Do not put the water-supply hose directly into the spray tank.
8. Do not blow out clogged nozzles or spray lines with your mouth.
9. Wash with soap and water exposed parts of body and clothes contaminated with insecticide.
10. Do not leave puddles of spray on impervious surfaces.
11. Do not apply insecticides to fish-bearing or other water supplies.
12. Do not apply insecticides, except in an emergency, to areas with abundant wildlife or to blossoming crops visited by bees. Avoid drift onto blossoming crops or onto bee hives.
13. Do not apply insecticides near dug wells or cisterns.
14. Do not spray when weather conditions favor drift.
15. Observe all precautions listed on the label.
16. To avoid bee kill, apply insecticides after bee activity has been completed for the day; use the least toxic materials. *Warn beekeepers that you are applying insecticides.*

1990 Insect Pest Management Guide

LIVESTOCK and LIVESTOCK BUILDINGS

CONTENTS

Special Review of Dichlorvos

Many insecticide products containing dichlorvos (DDVP) are registered and commonly used to control pests of livestock. Among such products are Ciovap (dichlorvos plus crotoxyphos), Ravap (dichlorvos plus stirofos), resin strips known as "No-Pest Strips" and "Farm Strips," Vapona (liquid concentrates and dry bait), and dichlorvos horse wormers.

As a result of studies commissioned by the National Toxicology Program, the U.S. Environmental Protection Agency (U.S. EPA) has recently classified dichlorvos as a probable human carcinogen. The U.S. EPA has initiated a special review of dichlorvos to evaluate the benefits and risks associated with its use in a variety of pest-control situations. The results of that review will determine the future of dichlorvos registrations and uses.

Until further information clarifies the risks associated with the use of dichlorvos, and until the special review results in continuation or cancellation of current registrations, livestock producers are advised not to purchase products containing dichlorvos. Although the use of dichlorvos according to label directions during the special review is legal, curtailing this use reduces any risks to human health during this process. For that reason, all listings of dichlorvos uses have been deleted from the 1990 issue of this publication.

Successful pest management is an essential part of efficient and profitable livestock production. Although pest-related losses are often inconspicuous, flies, lice, mites, and ticks can cause significant reductions in meat, milk, wool, and egg production. Several livestock pests also transmit important diseases.

Effective management of livestock pests should include the use of cultural, mechanical, and biological control tactics as well as the application of chemical insecticides. Insecticides should be viewed as supplements to, not replacements for, sanitation and sound cultural practices. Used properly, insecticides efficiently reduce pest populations without injuring livestock or threatening the safety of either the pesticide applicator or the ultimate consumer of animal products.

This publication provides recommendations for safe and effective use of livestock insecticides. It is revised annually; always use the current year's issue. Registration changes that occur between revisions will be announced to appropriate media sources and county Extension offices. If you have questions about the use of insecticides for livestock insect management, consult your county Extension adviser.

Selection of the insecticides listed on the following pages was based on EPA registrations and on efficacy data reported by entomologists of the University of Illinois College of Agriculture, the Illinois Natural History Survey, and other midwestern universities. If listed insecticides fail to provide pest control, please contact your county Extension adviser or the Entomology Extension office at the University of Illinois.

Additional sources of information. In the tables, leaflets outlining the life history, biology, and habits of livestock pests are indicated by the letters "NHE" and the leaflet number. Request these leaflets at your county Extension office or from Entomology Extension, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820. Additional pest management

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
In cooperation with ILLINOIS NATURAL HISTORY SURVEY CIRCULAR 898-90 (revised annually) October 1989

Prepared by Richard A. Weinzierl, Extension Entomologist

publications available from the Office of Agricultural Publications (54 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801) include Circular 899, *1990 Insect Pest Management Guide: Field and Forage Crops;* Circular 900, *1990 Insect Pest Management Guide: Home, Yard, and Garden;* Circular 925, *Insect Pests of Cattle;* Circular 897, *1990 Insect Pest Management Guide: Commercial Vegtetable Crops;* and Circular 1136, *Alfalfa Weevil Pest Management Program.*

Using livestock insecticides. The pesticide user is always reponsible for the results of insecticide applications to his livestock and crops, as well as for problems of pesticide drift and contamination. All users should observe the following rules.

- Read the label and follow directions and safety precautions. Be sure that the insecticide is specifically labeled for the pest and animal in question and the application method planned. THE LABEL IS THE LAW.
- Use face masks or respirators and protective clothing during spraying. Avoid breathing spray mist or dust.
- If pesticides are spilled on the skin or clothing, wash thoroughly with soap and water and change clothes.
- Do not eat, drink, or smoke when handling pesticides.
- Provide adequate ventilation when applying pesticides.
- Do not exceed registered rates of application. Improper or excessive applications can endanger livestock and result in illegal residues in meat and milk.
- Obey the preslaughter interval listed on the label.
- Avoid drift to adjacent cropland, yards, woodlots, lakes, or ponds. Some materials may injure or kill fish, wildlife, and crops.
- Do not treat animals that are sick, overheated, or stressed from shipping, dehorning, castration, recent weaning, and other causes.
- Avoid contamination of feed, mangers, water, milk, and milking equipment.
- Do not spread treated manure on crops that are not listed on the pesticide label.
- Accurately record all pesticide usage. Include the pesticide's trade name, formulation, dilution, application rate, and date of treatment.
- Store pesticides in their original, labeled containers, safely locked away from children, pets, and livestock.
- Dispose of empty pesticide containers promptly and properly according to specified recommendations. Do not breathe smoke from burning containers.
- Contact a physician at once in all cases of suspected poisoning. Symptoms of organophosphate poisoning include blurred vision, abdominal cramps, and tightness in the chest.

Poison Resource Centers. The Poison Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Resource Center will provide first-aid information and refer callers to local treatment centers if necessary.

Poison Resource Centers supplement, but do not replace, local emergency medical services. Do not delay calling local emergency medical personnel to request immediate assistance or transportation. If possible, have the pesticide container and label present when you call or reach a treatment center or hospital.

Chicago and northeast Illinois
1753 West Congress Parkway
Chicago, Illinois 60612
Telephone: 800-942-5969

Northern and central Illinois
530 N.E. Glen Oak
Peoria, Illinois 61603
Telephone: 800-322-5330

Central and southern Illinois
800 East Carpenter
Springfield, Illinois 62702
Telephone: 800-252-2022

A national pesticides telecommunications network can be reached by dialing 1-800-858-7378.

Preventing livestock poisoning. Every year livestock animals die after consuming pesticide granules, wettable powders, or dusts that have been spilled on trucks, wagons, or soil surfaces. Animals consume the pesticide alone or with feed grains or forage placed on the contaminated surface. Prevent livestock poisoning by properly containing and disposing of spilled pesticides and by storing all pesticides in locked facilities that are inaccessible to domestic and wild animals, as well as to children.

NOTE: The information in the following tables is for educational purposes only. Reference to commercial products or trade names does not constitute an endorsement by the University of Illinois and does not imply discrimination against other similar products. Trade names are presented for reasons of clarity only. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

Beef Cattle and Nonlactating Dairy Cattle

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE (NHE 18) $\frac{1}{16}$ to $\frac{1}{8}$ inch long. Biting lice are reddish, flattened, and active. Sucking lice are gray to blue and sluggish. Heavy populations cause poor growth, general unthriftiness, and anemia. Symptoms are rough, patchy hair coats and a dirty appearance. Lice are most troublesome during winter months.	Self-treatment devices such as back rubbers, face rubbers, and dust bags effectively control lice when used in conjunction with systemic insecticides applied from August through October for grub control. The systemics kill lice that are present on animals during the fall; the self-treating devices then hold louse populations below economic levels throughout the winter. Place rubbing devices and dust bags where cattle will use them. For back rubbers and face rubbers, mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or an oil recommended on the insecticide label. Mineral oil is less irritating than fuel oil. Do not use waste oil or motor oil. Keep dust bags dry. Service self-treating devices at least once per month.			
	Back rubber or face rubber (oilers)	Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days. Do not apply with oral drenches, with other internal medications such as phenothiazine, or with natural or synthetic pyrethroids, synergists, or organophosphates.
		malathion 57% EC	0.5 pt/1.5 gal fuel or mineral oil.	0 days.
	Dust bag	Products listed for use in dust bags can also be applied by hand-dusting. Follow label directions.		
		Co-Ral 1% D (coumaphos)	10 lb dust/bag. Use 1 bag/10-20 head.	0 days.
		Ectiban or Permectrin 0.25% D (permethrin)	10 lb dust/bag. Use 1 bag/10-20 head.	0 days.
		Rabon 3% D (stirofos)	4-8 lb dust/bag. Use 1 bag/10-20 head.	0 days.
	Spray	Apply sufficient spray to thoroughly wet each animal. Use up to 1 gallon finished spray per animal. Do not contaminate feed or water.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	2 qt 11.6% EC or 2 lb 25% WP/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle. Do not treat calves less than 3 months old or sick, convalescent, or stressed cattle. Do not spray within 10 days after shipping, weaning, or disease exposure. Do not spray in nonventilated areas. Do not apply in conjunction with other organophosphates, pyrethroids, synergists, or phenothiazine.
		Delnav 15% EC or 30% EC (dioxathion)	1 qt 15% EC or 1 pt 30% EC/25 gal water.	0 days. Do not treat more often than every 14 days. Do not use on dairy cattle or in dairy barns. Restricted-use.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Repeat treatment 14-21 days after first application. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for control of lice on beef cattle. Check product labels for dilution and application rates.)		
		malathion 57% EC	1 gal/100 gal water.	0 days. Do not apply to lactating dairy cattle or within 14 days of freshening. Do not treat calves less than 1 month old.
		Rabon 50% WP or 24% EC (stirofos)	4 lb 50% WP/75 gal water or 1.5 gal 24% EC/100 gal water.	0 days. Beef cattle only.
		methoxycholor 25% EC or 50% WP	2 qt 25% EC or 2 lb 50% WP/25 gal water.	0 days. Repeat treatment 14-21 days after first application. Do not use on dairy cattle or in dairy barns.
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal spray per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10-14 days.
	Pour-on or spot-on	Fall applications of systemic pour-ons and spot-ons such as Co-Ral (coumaphos), Warbex (famphur), Tiguvon (fenthion), Neguvon (trichlorfon), and Prolate (phosmet) for grub control also reduce louse populations. These treatments may not provide season-long louse control through the winter. Follow label directions concerning reuse after grub treatment cut-off dates. Products listed below effectively control lice, but do not provide grub control.		
		Dursban 44 (chlorpyrifos)	2 cc/100 lb body weight	14 days. Beef cattle only. Apply as spot treatment. Do not exeed 16 cc/animal. Do not treat calves under 3 months old or bulls over 8 months old. Do not treat purebred continental or exotic breed cattle such as Charolais, Chianina, Simmental, and Gelbveih. Do not retreat within 30 days. Do not use on cows within 21 days prior to calving or 14 days after calving.

Beef Cattle and Nonlactating Dairy Cattle, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE, cont.	Pour-on or spot-on, cont.	Lysoff 7.6% EC (fenthion)	1 pt/1 gal water. Use 1 fl oz/100 lb body weight.	21 days; 35 days if 2 applications are made. Do not apply within 28 days of freshening of dairy cattle. Pour evenly along back line. Do not treat calves under 3 months old or sick, convalescent, or stressed livestock. Do not use with other cholinesterase-inhibiting insecticides or drugs.
		Atroban Delice or Expar 1% (permethrin)	0.5 fl oz/100 lb body weight. Do not exceed 5 fl oz/animal.	0 days.
	Injection	Ivomec 1% (ivermectin)	Ready to use. 1 cc/110 lb body weight.	35 days. Inject subcutaneously. Use aseptic procedures. Do not use on dairy cattle of breeding age.
CATTLE GRUBS Larvae ("grubs") bore through the skin and migrate within the host to the skin of the back. Light infestations cause little or no reduction in the rate of gain or in feed efficiency. Hide damage can be economically important if cattle are slaughtered during the spring or early summer following grub emergence. The hairy, yellow and black adult flies, slightly smaller than honey bees, annoy grazing cattle.	Timing of grub control treatments is important. Systemic insecticides applied as pour-ons, spot-ons, or sprays travel within the animal's bloodstream and should be applied to control grubs 6 to 8 weeks before they migrate to the animal's back. Late treatments may cause host-parasite reactions with symptoms of bloat, hindquarter paralysis, or death. Systemic insecticides should be used on native beef cattle herds in August or September in southern Illinois, and in September or October in the northern half of the state. For native cattle, treat only summer-pastured cattle in areas with histories of grub problems. Cattle more than 3 years old rarely are economically infested. Animals in confinement are not attacked by ox warble flies (heel flies). Heel fly season and grub treatment dates are earlier for cattle grazed in southern states. Cattle feeders should either know the origin of feeder cattle to determine grub treatment dates or should purchase only cattle that have received grub treatments. Do not apply systemic insecticides in conjunction with or immediately after phenothiazine, with pyrethrins or synthetic pyrethroids or their synergists, or with other organophosphate insecticides. Do not treat cattle under stress from castration, dehorning, weaning, shipping, illness, or overexertion. Do not treat calves less than 3 months old.			
	Pour-on	Apply pour-ons using a long-handled dipper supplied by the manufacturer. Apply to the back line from the shoulder to the hip.		
		Co-Ral 4% (coumaphos)	Ready to use. Apply 0.5 fl oz/100 lb body weight.	0 days. Do not apply within 14 days of freshening of dairy cattle.
		Neguvon 8% (trichlorfon)	Ready to use. Apply 0.5 fl oz/100 lb body weight. Do not exceed 4 fl oz/animal.	21 days. Do not apply within 7 days of freshening of dairy cattle.
		Prolate (GX-118) 11.6% E (phosmet)	1 gal/2 gal water. Apply 1 fl oz/100 lb body weight. Do not exceed 8 fl oz/animal.	21 days. Do not apply to dairy animals.
		Tiguvon 3% (fenthion)	Ready to use. Apply 0.5 fl oz/100 lb body weight.	35 days. Do not apply within 28 days of freshening of dairy cattle.
		Warbex 13.2% (famphur)	Ready to use. Apply 0.5 fl oz/100 lb body weight. Do not exceed 4 fl oz/animal.	35 days. Do not apply within 21 days of freshening of dairy cattle. Do not use on Brahmans or Brahman crossbreeds.
	Spot-on	To apply spot-ons, use the applicator system provided by the manufacturer. Apply the material to a single location on the back midline.		
		Spotton 20% (fenthion)	Ready to use. Apply 4 cc/300 lb body weight. Do not exceed 20 cc/animal.	45 days. Do not treat dairy cattle of breeding age.
	Spray	Use high-pressure sprays (250-350 psi) to apply 3 to 4 quarts of finished spray per animal. Because few farm sprayers generate sufficient pressure for proper application, veterinarians and commercial applicators with appropriate livestock spray equipment should be contacted to apply grub sprays. Use a pencil stream of spray directed at right angles to the sides and back. Treat 10 or fewer animals at one time. Do not contaminate feed or water.		
		Co-Ral 25% WP or 11.6% EC (coumaphos)	12-16 lb 25% WP or 8-12 qt 11.6% EC/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle.
		Prolate (GX-118) 11.6% EC (phosmet)	2 gal/100 gal water.	21 days. Beef cattle only.
	Injection	Ivomec 1% (ivermectin)	Ready to use. 1 cc/110 lb body weight.	35 days. Inject subcutaneously. Use aseptic procedures. Do not use on dairy cattle of breeding age.

Beef Cattle and Nonlactating Dairy Cattle, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
MANGE MITES Microscopic mites live on the skin or burrow into it. Lesions vary with mite species. Infestations are greatest when cattle are crowded in shelters during winter months.	Chorioptic mange is the most prevalent mite-induced disorder of Illinois cattle. Infested cattle may or may not develop lesions; lesions usually occur as localized nodules that exude serum. They are most numerous from the tailhead to the hind heels. Insecticides listed previously for louse control on beef cattle also control chorioptic mange mites. Cattle scabies (psoroptic mange) is a quarantinable disease. Its symptoms are lesions that occur first on the withers, over the back, and at the tailhead. Small wounds cause itching, and rubbing leads to abscesses, especially on the shoulders and rump. Mites move to edges of scabs, causing lesions to enlarge and coalesce. Scabs may cover much of the body. Accurate diagnosis requires microscopic examination of skin scrapings. Where cattle scabies is detected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217) 782-4944.			
TICKS 8-legged adults of most species are reddish brown and less than ¼ inch long. Engorged females may exceed ½ inch in length. Ticks are blood feeders and disease vectors.	Ticks rarely pose an economic threat to cattle in Illinois. Problems are most likely where cattle graze in brushy or wooded areas.			
	Spray	Apply sufficient spray to thoroughly wet each animal; use up to 1 gallon finished spray per animal. Do not contaminate feed or water.		
		Co-Ral 25% WP or 11.6% EC (coumaphos)	4 lb 25% WP or 1 gal 11.6% EC/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle. Do not treat calves less than 3 months old or sick, convalescent, or stressed cattle. Do not spray within 10 days after shipping, weaning, or disease exposure. Do not spray in nonventilated areas. Do not apply in conjunction with phenothiazine, pyrethroids, synergists, or systemic organophosphate insecticides.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Do not apply more than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for control of ticks on cattle. Check product labels for dilution and application rates.)		
		malathion 57% EC	1-2 gal/100 gal water.	0 days. Do not apply to dairy cattle within 14 days of freshening. Do not treat calves less than 1 month old.
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal spray per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10-14 days.
MOSQUITOES Annoyance may cause cattle to bunch in or near buildings and reduce their grazing. High populations may cause reductions in rate of weight gain.	Mosquito populations are greatest near low, wet areas, ponds, or slow-moving streams. Reduction of mosquito breeding sites is necessary for long-term control. For information on source reduction and area treatments for mosquito control, see "Mosquitoes in Illinois: Recommendations for Prevention and Control," an annually revised publication available from the Illinois Department of Public Health in Springfield. The insecticides listed below provide some short-term relief for treated animals, but frequent applications are not economical or recommended.			
	Spray (to animals)	Ectiban 5.7%	1 qt/100 gal water.	0 days. Do not apply more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes and horse flies on cattle. Check product labels for dilution and application rates.)		
		pyrethrin (0.1%) plus synergist	Mist 1-2 fl oz/animal.	0 days. Do not contaminate feed or water. Do not wet skin.
HORSE FLIES, DEER FLIES (NHE 60) Large flies that feed on the back, shoulders, neck, and head. Blood feeding annoys cattle and reduces grazing and weight gain. Wounds attract other flies.	Adequate and practical control methods for horse flies and deer flies on pastured beef cattle are not available. Insecticide applications provide some relief but do not provide long-term control. Place cattle in barns or sheds to protect them from horse flies and deer flies.			
	Spray	Ectiban 5.7%	1 qt/100 gal water.	0 days. Do not apply more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes and horse flies on cattle. Check product labels for dilution and application rates.)		
		pyrethrin (0.5-1.0%) plus synergist	0.5% oil is ready to use; apply 2 fl oz/animal 3 times per week. Mix 1 gal 1% EC/10 gal water; apply 1 to 2 pt/animal every 3 days.	0 days. Apply to head, back, sides, belly, and legs. Do not contaminate feed or water.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
PASTURE FLIES (HORN FLIES, FACE FLIES, STABLE FLIES) **Horn flies** (NHE 59) are smaller than house flies but are similarly colored and marked. They have piercing mouthparts and are blood feeders. Horn flies congregate about the back, shoulders, and horns; on hot days they are mostly on the shady side of the animal or on the belly. Horn flies seldom follow animals into barns or sheds. **Face flies** (NHE 106) resemble house flies but are slightly larger and darker. Only females frequently visit cattle. They feed on secretions about the eyes, nose, and mouth. **Stable flies** (NHE 61) resemble house flies but have a piercing proboscis that protrudes from the front of the head. Stable flies are blood feeders that often attack the lower portion of the front legs. Stable flies attack both pastured and feedlot cattle.	**Threshold Infestations and Adequate Levels of Control:** Horn fly infestations of up to 100 to 200 flies per animal produce little or no effect on the rate of gain. In Illinois, control programs utilizing dust bags or oilers often reduce horn fly infestations to 10 to 50 flies per animal. The use of dust bags or oilers provides adequate and economical control of horn flies and usually does not favor rapid development of insecticide resistance (as do ear tags). Available data do not support any estimates of what constitutes an economically damaging number of face flies or an acceptable level of face fly control. Although face flies annoy cattle, even heavy infestations do not cause reductions in the rate of gain. Face flies can transmit the pathogen that causes pinkeye, but pinkeye outbreaks also occur in the absence of face flies. Research indicates that as few as 1 to 5 stable flies per leg can reduce cattle performance in some conditions. Nonetheless, there are no effective insecticide applications for reducing stable fly attacks on pastured cattle. Although sprays directed at animals' legs may provide temporary relief, no long-term control is accomplished. Moving cattle into shelters reduces annoyance by horn flies and face flies, but it does not deter stable fly attack.			
	Back rubber or face rubber (oilers)	Mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or a label-recommended mineral oil. Mineral oils are less irritating than fuel oils. Do not use waste oil or motor oil. Service the rubbing device at least one per week. Self-treating devices are effective only if they are used regularly. Place rubbing devices in the entryways to water or mineral feeders to ensure usage. Effective horn fly control can be achieved with forced-use oilers; partial control of face flies is provided by these devices. Oilers do not control stable flies.		
		Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days.
		Delnav 15% EC or 30% EC (dioxathion)	2 qt 15% EC or 1 qt 30% EC/5 gal fuel or mineral oil.	0 days. Beef cattle only.
		Ectiban or Insectrin 5.7% EC (permethrin)	1 qt/10 gal diesel oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Permectrin II 10% EC (permethrin)	1 qt/20 gal fuel or mineral oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
	Dust bag	Dust bags are effective only if they are used regularly. Place them in the entryways to water or mineral feeders to ensure use. Keep dust bags dry and well charged; service at least once per week. Forced-use dust bags that contact the animal's face provide effective horn fly control and significant reductions in face flies; dust bags do not effectively control stable flies.		
		Co-Ral 1% D (coumaphos)	10 lb/bag.	0 days.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	10 lb/bag.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		malathion 4% plus methoxychlor 5% D	1 10-lb bag/ 10-15 animals.	0 days. Beef cattle only.
		Rabon 3% D (stirofos)	4-8 lb/bag.	0 days.
	Feed additive	Feed additives prevent the development of face fly and horn fly larvae in cattle dung. Stable flies do not develop in fresh dung and are not controlled by feed additives. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not also receive boluses or feed additives. Animals must consume the recommended dosage for the feed additive to be effective.		
		Altosid 0.02% (methoprene)	0.25-0.5 lb/100 lb body weight/ animal/month.	0 days. Feed mineral mix or block from May to September.
		Rabon 7.76% Oral Larvacide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Use from May through September. Mix with complete feeds, concentrates, or protein supplements.
	Bolus	Boluses release an active ingredient that prevents the development of face fly and horn fly larvae in treated dung. Stable flies do not develop in fresh dung and are not controlled by bolus use. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not receive boluses or feed additives.		
		Vigilante 9.7% bolus (diflubenzuron)	1 bolus/550 to 1100 lb body weight.	0 days. Use standard balling gun. Do not administer to animals weighing less than 300 pounds. No more than 1 bolus per animal. Boluses can be divided in half to achieve correct rate.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
PASTURE FLIES, cont.	Ear tag or ear tape	Before widespread development of resistance in the horn fly, ear tags and tapes impregnated with pyrethroid insecticides such as fenvalerate, flucythrinate, or permethrin effectively controlled horn flies and gave some control of face flies infesting pastured cattle. One tag or tape per cow effectively controlled horn flies for up to 20 weeks. However, midseason control failures (indicating horn fly resistance) have occurred throughout Illinois in recent years.		
		Although Max-Con tags containing cypermethrin (a newer pyrethroid) plus Dursban (an organophosphate) plus a synergist are slightly more effective against resistant horn flies than the original pyrethroid tags, they do not consistently control resistant populations and can be expected to cause an increase in the level of pyrethroid resistance. Pyrethroid tags containing the more active compound cyhalothrin (Saber tags) have initially controlled pyrethroid-resistant horn flies, but trials conducted in the southeastern United States have shown that these tags also intensify resistance and then fail to provide control.		
		Because resistance has already reduced the performance of pyrethroid tags and tapes, and because continued use of any pyrethroids in such devices is likely to result in even higher levels of resistance (levels that may allow horn fly survival even when pyrethroid sprays or dusts are applied), this publication recommends that no tags containing any pyrethroid insecticide be used in Illinois at this time. Tags and tapes to be avoided include those containing fenvalerate (including Ectrin, Insecta-Shield, Ear Tag Plus, Starbar, and Vet Shack), permethrin (including Atroban, Apollo, Expar, Insecta-Gard, Gard Star, Fearing Du-flex, Permectrin, and Ear Force Ranger), and flucythrinate (Guardian). Also avoid Max-Con tags, Saber tags, and any other tags containing a pyrethroid insecticide. NOTE: Although abstaining from pyrethroid tag use is strongly recommended, these products remain registered and legal to use.		
		Tags containing the organophosphates diazinon (Terminator or OPtimizer tags) or pirimiphos-methyl (Tomahawk tags) effectively control horn flies (including pyrethroid-resistant horn flies), but they are somewhat less effective than pyrethroid tags for face fly control. Two tags per cow will provide horn fly control for approximately 16 weeks. Attach tags in late May or early June after fly populations have begun to increase. Remove tags in September or October. The management practice most likely to slow the development of horn fly resistance to the organophosphates used in ear tags is the avoidance of widespread reliance on such tags for pasture fly control. Where practical, use dust bags, oilers, or sprays containing insecticides other than those in ear tags; using feed additives or boluses is another (though slightly less effective) alternative.		
		diazinon 20% tag (Terminator or OPtimizer)	2 tags per animal.	0 days. Do not apply to calves less than 3 months old. Do not apply to lactating dairy cattle. Remove in fall or before slaughter.
		pirimiphos-methyl 20% tag (Tomahawk)	2 tags per animal.	0 days. Do not apply to lactating dairy cattle. Remove in fall or before slaughter.
	Spray	Sprays directed to animals should not contaminate feed or water. Do not use sprays containing fenvalerate or permethrin to control resistant horn flies that are not controlled by pyrethroid ear tags.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	2 qt 11.6% EC or 2 lb 25% WP/ 100 gal water. Completely wet skin to runoff.	0 days. Do not apply to dairy cattle within 14 days of freshening.
		Delnav 15% EC or 30% EC (dioxathion)	1 qt 15% EC or 1 pt 30% EC/25 gal water.	0 days. Do not use more often than every 14 days. Do not use on dairy cattle or in dairy barns. Restricted-use.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water. Thoroughly wet animals.	0 days. Repeat as needed, but not more often than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for control of pasture flies on cattle. Check product labels for dilution and application rate.		
		methoxychlor 25% EC or 50% WP	2 qt 25% EC or 2 lb 50% WP/25 gal water.	0 days. Do not use on dairy cattle or in dairy barns.
		Rabon 50% WP (stirofos)	4 lb/75 gal water. Use ½ to 1 gal/animal.	0 days. Beef cattle only.
	Trap	Large "walk-through" fly traps positioned at pasture gates (where animals must pass through the traps regularly) can reduce horn fly numbers by up to 70 percent. No insecticides are used in these traps. Additional information and plans for construction of these traps are available from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820.		

Lactating Dairy Cattle

Insecticides listed in this section are registered for use on lactating dairy cattle. Most insecticides listed for use on beef cattle can be applied to nonlactating dairy cattle if the specified interval between application and freshening is observed. Follow all label directions.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE (NHE 18)	Dust bag	Place dust bags at milkroom exits. Keep bags charged and dry, and service at least once per month. (Co-Ral 1% dust and Ectiban and Permectrin 0.25% dusts can be used for direct hand-dusting; follow label directions.)		
1/16 to 1/8 inch long. Biting lice are reddish, flattened, and active. Sucking lice are gray to blue and sluggish.		Co-Ral 1% D (coumaphos)	10 lb dust/bag.	0 days.
		Ectiban or Permectrin 0.25% D (permethrin)	10 lb dust/bag. Self-treating.	0 days.
Heavy populations cause reduced milk production and anemia. Symptoms are rough, patchy hair coats and a dirty appearance. Most troublesome in winter.	Spray	Apply sufficient spray to thoroughly wet each animal; use up to 1 gallon finished spray per animal. Do not contaminate feed, water, milk, or milking equipment.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	1 qt 11.6% EC or 1 lb 25% WP/100 gal water.	0 days. Do not treat calves less than 3 months old.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Repeat application 14-21 days after first treatment.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for the control of lice on dairy cattle. Check product labels for dilution and application rates.)		
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10-14 days.
	Pour-on	Atroban Delice or Expar 1% (permethrin)	0.5 fl oz/100 lb body weight. Do not exceed 5 fl oz/animal.	0 days.
CATTLE GRUBS	No pesticides are currently registered for control of cattle grubs on lactating dairy cattle.			
MANGE MITES Microscopic mites live on or within skin. Lesions vary with mite species. Infestations are greatest when cattle are crowded in shelters during winter.	Mange caused by chorioptic mites (barn itch mites) is the most common mite-induced disorder of Illinois dairy cattle. Infested cattle may or may not develop lesions; lesions usually appear as localized nodules that exude serum. Lesions are most prevalent from the tailhead to the hind heels. Insecticides listed for louse control on dairy cattle also control chorioptic mange. Cattle scabies (psoroptic mange) is a quarantinable disease. Its symptoms are lesions that occur first at the withers, over the back, and at the tailhead. The wounds itch, and rubbing leads to absesses, especially on the shoulders and rump. Mites move to edges of scabs, causing lesions to enlarge and coalesce. Scabs may cover much of the body. Accurate diagnosis requires microscopic examination of skin scrapings. Where cattle scabies is detected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217) 782-4944.			
TICKS	Ticks are rarely economically important on Illinois dairy cattle. Problems are most likely where cattle graze in brushy or wooded areas.			
8-legged adults of most species are reddish brown and less than 1/4 inch long. Engorged females may exceed 1/2 inch in length. Ticks are blood feeders and disease vectors.	Spray	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Do not apply more often than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for the control of ticks on dairy cattle. Check product labels for dilution and application rates.		
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10-14 days.
MOSQUITOES	Mosquito populations are greatest near low, wet areas, ponds, and slow-moving streams. Reduction of mosquito breeding sites is necessary for long-term control. For information on source reduction and area treatments for mosquito control, see "Mosquitoes in Illinois: Recommendations for Prevention and Control," an annually revised publication available from the Illinois Department of Public Health in Springfield. The insecticides listed below provide some short-term relief for treated animals, but frequent applications are not economical or recommended.			
Blood feeding. Annoyance may cause cattle to remain in buildings and reduce their grazing.	Spray (to animals)	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt per animal.	0 days. Do not apply more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes on dairy cattle. Check product labels for dilution and application rates.)		
		pyrethrin (0.03-0.10%) plus synergist (0.5-1.0%)	Ready to use. Mist 1-2 fl oz/animal.	0 days. Do not wet skin. Do not contaminate feed, water, milk, or milking equipment. Repeat as necessary.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
PASTURE FLIES (HORN FLIES, FACE FLIES, STABLE FLIES)	**Threshold Infestations and Adequate Levels of Control:** In Illinois, control programs utilizing dust bags or oilers often reduce horn fly infestations to 10 to 50 flies per animal. The use of dust bags or oilers provides adequate and economical control of horn flies and usually does not favor rapid development of insecticide resistance (as do ear tags).			
Horn flies (NHE 59) are smaller than house flies but are similarly colored and marked. They have piercing mouthparts and are blood feeders. Horn flies congregate about the back, shoulders, and horns; on hot days they are mostly on the shady side of the animal or on the belly. Horn flies seldom follow animals into barns or sheds.	Available data do not support any estimates of what constitutes an economically damaging number of face flies or an acceptable level of face fly control. Although face flies annoy cattle, even heavy infestations do not cause reductions in milk production. Face flies can transmit the pathogen that causes pinkeye, but pinkeye outbreaks also occur in the absence of face flies.			
Face flies (NHE 106) resemble house flies but are slightly larger and darker. Only females frequently visit cattle. They feed on secretions about the eyes, nose, and mouth.	Research indicates that as few as 1 to 5 stable flies per leg can reduce milk production in some conditions. Spraying cattle's legs as they exit the milkroom provides temporary relief, but no long-term control is accomplished.			
Stable flies (NHE 61) resemble house flies but have a piercing proboscis that protrudes from the front of the head. Stable flies are blood feeders that often attack the lower portion of the front legs. Stable flies attack both pastured and feedlot cattle.	Moving cattle into shelters reduces annoyance by horn flies and face flies, but it does not deter stable fly attack.			
	Back rubber or face rubber (oilers)	Mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or a label-recommended mineral oil. Mineral oils are less irritating than fuel oils. Do not use waste oil or motor oil. Service the oiler at least once per week. For self-treating devices to be effective, cattle must use them frequently. Place oilers in the entryways to water or mineral feeders or in the milking room exit. Well-used back rubbers or face rubbers will control horn flies and provide some face fly control. They will not control stable flies.		
		Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days.
		Ectiban or Insectrin 5.7% EC (permethrin)	1 qt/10 gal oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Permectrin II 10% EC (permethrin)	1 qt/20 gal fuel or mineral oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
	Dust bag	For self-treating devices to be effective, cattle must use them regularly. Place dust bags in the entryways to water or mineral feeders or in the milking room exit. Keep dust bags dry; service at least once per week. Dust bags will control horn flies and provide some reduction in face fly problems. They will not control stable flies. (NOTE: Insecticide dusts listed below can also be used for direct hand-dusting; follow label directions.)		
		Co-Ral 1% D (coumaphos)	10 lb/dust bag.	0 days. Do not treat calves less than 3 months old.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	10 lb/dust bag.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Rabon 3% D (stirofos)	4-8 lb/dust bag.	0 days.
	Spray	It is important that the following sprays do not contaminate feed, water, milk, or milking equipment. Do not use sprays containing fenvalerate or permethrin to control resistant horn flies that are not controlled by pyrethroid ear tags.		
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Re-treat as needed, but not more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for pasture fly control on dairy cattle. Check product labels for dilution and application rates.)		
		pyrethrin (0.1%) plus synergist	Ready to use. Apply 1-2 fl oz/animal.	0 days. Repeat as needed.
	Feed additive	Feed additives prevent the development of face fly and horn fly larvae in cattle dung. Stable flies do not develop in fresh dung and are not controlled by feed additives. Face flies and horn flies migrate considerable distances, so larval control in the dung of a single herd may not substantially reduce fly populations if other herds in the area do not also receive boluses or feed additives. Animals must consume the recommended dosage for the feed additive to be effective.		
		Altosid 0.02% (methoprene)	0.25-0.5 lb/100 lb body weight/month.	0 days. Feed mineral mix or blocks from May to September.
		Rabon 7.76% Oral Larvicide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Feed in complete feeds, concentrates, or protein and mineral supplements from May to September.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
PASTURE FLIES, cont.	Bolus	Boluses release an active ingredient that prevents the development of face fly and horn fly larvae in treated dung. Stable flies do not develop in fresh dung and are not controlled by bolus use. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not receive boluses or feed additives.		
		Vigilante 9.7% bolus (diflubenzuron)	1 bolus/550 to 1100 lb body weight.	0 days. Use standard balling gun. Do not administer to animals weighing less than 300 pounds. No more than 1 bolus per animal. Boluses can be divided in half to achieve correct rate.
	Ear tag or ear tape	Before widespread development of resistance in the horn fly, ear tags and tapes impregnated with pyrethroid insecticides such as fenvalerate, flucythrinate, or permethrin effectively controlled horn flies and gave some control of face flies infesting pastured cattle. One tag or tape per cow effectively controlled horn flies for up to 20 weeks. However, midseason control failures (indicating horn fly resistance) have occurred throughout Illinois in recent years. Although Max-Con tags containing cypermethrin (a newer pyrethroid) plus Dursban (an organophosphate) plus a synergist are slightly more effective against resistant horn flies than the original pyrethroid tags, they do not consistently control resistant populations and can be expected to cause an increase in the level of pyrethroid resistance. Pyrethroid tags containing the more active compound cyhalothrin (Saber tags) have initially controlled pyrethroid-resistant horn flies, but trials conducted in the southeastern United States have shown that these tags also intensify resistance and then fail to provide control. (Saber tags are not registered for use on lactating dairy cattle.) Because resistance has already reduced the performance of pyrethroid tags and tapes, and because continued use of any pyrethroids in such devices is likely to result in even higher levels of resistance (levels that may allow horn fly survival even when pyrethroid sprays or dusts are applied), this publication recommends that no tags containing any pyrethroid insecticide be used in Illinois at this time. Tags and tapes to be avoided include those containing fenvalerate (including Ectrin, Insecta-Shield, Ear Tag Plus, Starbar, and Vet Shack), permethrin (including Atroban, Apollo, Expar, Insecta-Gard, Gard Star, Fearing Du-flex, Permectrin, and Ear Force Ranger), cypermethrin (Max-Con), and flucythrinate (Guardian). NOTE: Although abstaining from pyrethroid tag use is strongly recommended, these products remain registered and legal to use. Tags containing the organophosphate Rabon (stirofos) provide fly control for approximately 6 weeks after application. The organophosphates diazinon (Terminator and OPtimizer tags) and pirimiphos-methyl (Tomahawk tags) should **not** be used on lactating dairy cattle.		

Hogs

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
MANGE MITES (AND LICE) Microscopic mites feed on or within skin and cause mange.	Although mange mites and lice are blamed for substantial losses in swine production, controlled studies indicate that otherwise healthy pigs suffer little or no reduction in the rate of gain or feed efficiency when infested with mange mites and lice. Managing lice and mange mites remains an important step in swine production, but keeping every animal louse-free and mange-free through the time of sale and slaughter is probably **not** economically justified. Mange mites and lice are spread by direct contact among animals. They may survive off the host animal for short periods in bedding, but they do not infest animals other than swine. Prevent mange outbreaks by isolating and treating any new animals — especially boars — before adding them to the herd. (SPF breeding stock are treated and declared free of mange and lice before sale.) Thoroughly clean and disinfect pens before using them to hold uninfested animals. To prevent infestation of newborn pigs, treat boars before the breeding season and treat sows before farrowing. It is often necessary to treat all animals in contact with those infested by mange mites or lice. It is also wise to isolate carrier animals to prevent the unnecessary spread of these pests from animal to animal.			

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
MANGE MITES cont. **Sarcoptic mange** usually starts at the head and then spreads back; infested skin becomes dry, scurfy, or leathery. Rubbing may lead to raw or scabby areas. **Demodectic mange** is characterized by hard, round swellings on or below the skin surface.	The insecticides listed below will help to control sarcoptic mange. There is no satisfactory chemical control for the hog follicle mites that cause demodectic mange. Isolate hogs with demodectic mange. Kill and destroy severely infested animals; market for slaughter the animals that are severely attacked. Clean and disinfect pens, sheds, and other infested areas before moving in uninfested animals. Follow label precautions against the simultaneous use of organophosphate sprays, dusts, or pour-ons with similar medications used for internal parasite control. Do not contaminate feed or water.			
	Spray	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Spray animals thoroughly.	5 days. Repeat application after 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for control of hog lice and mange. Check product labels for dilution and application rates.)		
		Ectrin 10% WDL (fenvalerate)	1 qt/50 gal water. Spray each animal thoroughly.	1 day. Repeat application in 14 days if necessary.
		lindane 12.4% EC or 20% EC	3 pt 12.4% EC or 1 qt 20% EC/100 gal water. Spray animals thoroughly.	30 days. Treat twice at a 7-day interval. Do not treat pigs less than 3 months old. Do not treat sows within 2 weeks before farrowing or 3 weeks after farrowing. Restricted-use.
		malathion 57% EC	1 qt/15 gal water. Treat animals, bedding, and walls thoroughly.	0 days. Do not treat pigs less than 1 month old. Repeat treatment after 10 days.
		Prolate 11.6% EC (phosmet)	2 qt/50 gal water. Treat animals thoroughly.	1 day. Do not treat pigs less than 3 months old.
		Taktic 12.5% EC (amitraz)	1 qt/50 gal water. Spray animals, bedding, and walls thoroughly.	1 day. Apply spray within 6 hours after mixing. Repeat application in 7-10 days.
	Dust	malathion 4-5% D	Thoroughly cover animals over 1 month old. Also treat pens and bedding. Use ¼-½ tbsp/pig for pigs less than 1 month old.	0 days. Repeat as needed. Gives only partial control of mange mites.
	Injection	Ivomec 1% (ivermectin)	10 mg/75 lb body weight.	18 days. Inject subcutaneously. Use aseptic procedures.
LICE Up to ⅙ inch long. Hog lice are bluish black in color. They suck blood from infested animals.	Insecticides listed for controlling mange mites on hogs will also control lice. Do not contaminate feed or water. Follow label precautions against the simultaneous use of organophosphate sprays, dusts, or pour-ons with medications used for internal parasite control.			
	Spray	Co-Ral 25% WP (coumaphos)	2 lb/100 gal water. Spray each animal thoroughly.	0 days. Do not treat animals less than 90 days old. Apply a second spray 10-14 days after first.
		methoxychlor 50% WP	8 lb/100 gal water. Spray each animal thoroughly.	0 days. Make second application 14 days after first if needed.
	Dust	Co-Ral 1% D (coumaphos)	1 oz/animal.	0 days. Dust especially around shoulders and back. Repeat as needed, but not more than once every 10 days.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	1 oz/animal.	5 days. Make second application 14 days after first.
		Rabon 3% D (stirofos)	3-4 oz/animal; 1 lb/150 sq ft of bedding for severe infestations.	0 days. Do not re-treat for 14 days.
	Pour-on	Ectrin 10% WDL (fenvalerate)	1 qt/25 gal water. Pour 4 fl oz/animal on head and back midline.	1 day. Add wetting agent according to label directions. Repeat application in 14 days if necessary.
		Tiguvon 3% Pour-On (fenthion)	0.5 fl oz/100 lb body weight.	14 days. May be used on gestating and lactating sows. Do not re-treat within 35 days.

Sheep

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
KEDS, LICE (NHE 53)	Spray	Apply enough spray to thoroughly cover each animal. Do not contaminate feed or water.		
Sheep keds (also called sheep ticks) are flattened, wingless, reddish brown flies about the size of house flies.		Co-Ral 25% WP (coumaphos)	*Lice:* 2 lb/100 gal water. *Keds:* 4 lb/100 gal water.	15 days. Do not treat lambs less than 3 months old.
Lice reach $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. Biting lice are flattened and yellowish to reddish in color. Sucking lice are oval and bluish gray.		diazinon 50% WP	0.5 lb/100 gal water. Use 1 gal/animal.	14 days. Use high pressure and volume. Do not treat lambs less than 2 weeks old.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		Ectrin 10% WDL (fenvalerate)	1 qt/100 gal water. Wet each animal with up to 1 qt of spray.	2 days. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
		malathion 57% EC	1 gal/100 gal water.	0 days. Do not treat lambs less than 1 month old.
		Marlate 50% WP (methoxychlor)	8 lb/100 gal water. Spray each animal thoroughly.	0 days.
	Dip	Co-Ral 25% WP (coumaphos)	*Lice:* 2 lb/100 gal water. *Keds:* 4 lb/100 gal water.	15 days. Do not dip lambs less than 3 months old.
		Del-Tox 20.4% EC (dioxathion)	2 qt/100 gal water.	0 days. Do not dip lambs less than 3 months old or sick, convalescent, or stressed animals. Prevent ingestion of dip. Dioxathion is available in additional formulations including Co-Nav, a restricted-use product.
	Dust	Co-Ral 0.5% D	Follow label directions.	15 days. Treat once after shearing. Do not treat lambs less than 3 months old.
		diazinon 2% D	1½ oz/animal.	14 days. Do not treat lambs less than 2 weeks old.
		malathion 4-5% D	1-2 oz/animal.	0 days. Repeat application in 2-3 weeks if needed. Do not treat lambs less than 1 month old.
		Marlate 50% WP (methoxychlor)	1 tbsp/animal.	0 days. Treat only once.
	Pour-on	Ectrin 10% WDL (fenvalerate)	2 qt/25 gal water. Pour 4 fl oz/animal down midline of back.	2 days. Add wetting agent according to label directions. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
WOOL MAGGOTS	Spray	Reduce wool maggot attacks by tagging sheep (shearing under the tail and between the hind legs), docking, and castrating before May. Practice good sanitation. Shear around and direct sprays to the infested areas.		
Cream-colored maggots are larvae of blow flies. Maggots live in wet, matted wool near the rear of the animal and in matted wool surrounding wounds.		Co-Ral 25% WP (coumaphos)	4 lb/100 gal water. Use 1 gal/animal.	15 days. Do not treat lambs less than 3 months old.
		diazinon 50% WP	0.5 lb/100 gal water. Use 1 gal/animal.	14 days. Do not treat lambs less than 2 weeks old.
SCAB MITES (SCABIES, WET MANGE)	Sheep scab is a quarantinable disease. Infested animals shed wool; skin becomes roughened and crusted. Where infestations are suspected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217) 782-4944.			
HORN FLIES (NHE 59) **FACE FLIES** (NHE 106)	Spray	Co-Ral 25% WP (coumaphos)	2 lb/100 gal water.	15 days. Do not treat lambs less than 3 months old.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Apply 1-2 qt/animal.	0 days. Do not treat more often than every 14 days.
		Marlate 50% WP (methoxychlor)	2 lb/100 gal water.	0 days. Repeat treatment every 3 weeks as needed.
		pyrethrin (0.05-0.10%) plus synergist (0.5-1.0%)	1-2 fl oz/animal.	0 days. Apply daily to head, neck, and front legs as a fine mist. Do not wet hair or skin.

Goats

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE (NHE 53)	Spray	Ectrin 10% WDL (fenvalerate)	1 qt/100 gal water. Wet each animal with up to 1 qt of spray.	2 days. Do not apply to lactating goats. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
	Pour-on	Ectrin 10% WDL (fenvalerate)	1 qt/25 gal water. Pour 4 fl oz/animal down midline of back.	2 days. Do not apply to lactating goats. Add wetting agent according to lable directions. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
FACE FLIES (NHE 106), **HORN FLIES** (NHE 59), **STABLE FLIES** (NHE 61) **HORSE FLIES, DEER FLIES** (NHE 60)	Spray	pyrethrin (0.05-0.10%) plus synergist (0.5-1.0%)	1-2 fl oz/animal.	0 days. Apply to head, neck, and front legs as a fine mist. Do not wet hair or skin.

Poultry

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE, NORTHERN FOWL MITES (BIRD TREATMENT) (NHE 54)	Spray	Co-Ral 25% WP (coumaphos)	*Lice:* 6 oz/5 gal water. *Mites:* 3 oz/5 gal water. Use 1 gal/100-125 birds, or 0.5 fl oz/bird.	0 days. Do not treat more than once per week. Do not treat within 10 days of vaccination or stress.
Chicken lice are flat-bodied, straw-colored, 1/16-inch-long lice with chewing mouthparts. They feed on feathers and skin flakes, irritating birds. Severe infestations reduce egg production. **Northern fowl mites** are dark red to black blood feeders that build up in the vent area. Mature mites are roughly 1/25 inch long. Feathers around the vent appear grayish or black from accumulation of mites, mite eggs, and excrement. Severe infestations reduce egg production and can cause death. Northern fowl mites are most troublesome in winter.		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 gal/100 birds.	0 days. Treat vent area thoroughly.
		malathion 57% EC	1 fl oz/gal water. Use 1 gal/100-125 birds.	0 days. Repeat treatment in 4-8 weeks or when necessary.
		Permectrin II 10% EC or Atroban, Expar, or Permaban 11% EC (permethrin)	1 qt/50 gal water. Use 1 gal/100 birds.	0 days. Treat vent area thoroughly.
		Rabon 50% WP (stirofos)	6.5% oz/5 gal water. Use 1 gal/100 birds or 1 fl oz/bird using at least 100-125 psi.	0 days. Do not treat more than once every 14 days.
		Sevin 50% WP or 80% SP (carbaryl)	6 oz 50% WP or 4 oz 80% SP/5 gal water. Use 1 gal/100 birds.	7 days. Repeat treatment in 4 weeks if necessary.
	Dust	Ectiban or Permectrin 0.25% D (permethrin)	Use 1 lb/100 birds.	0 days. Apply with shaker or hand duster. Treat vent area thoroughly.
		malathion 4-5% D	Use 1 lb/100 birds.	0 days. Apply with shaker or hand duster.
		Rabon 3% D (stirofos)	Use 1 lb/300 birds.	0 days. Apply with hand or power duster. Do not treat more than once every 14 days.
		Sevin 5% D (carbaryl)	Use 1 lb/100 birds.	7 days. Apply with shaker or hand duster. Do not treat more than once every 4 weeks.
	Strip	Permectrin 10% strip (permethrin)	1 or 2 strips per cage of up to 9 hens.	0 days. For northern fowl mite control.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE, CHICKEN MITES, NORTHERN FOWL MITES (POULTRY HOUSE AND LITTER TREATMENT) (NHE 54) **Chicken mites** (or roost mites) are bright to dark red and $\frac{1}{25}$ inch long. They hide in cracks and crevices during the day and feed on birds at night. They are most prevalent in spring, summer, and fall, not in winter.	Spray	Co-Ral 25% WP (coumaphos)	6 oz/5 gal water. Use 1 gal/1,000 sq ft.	0 days. Apply thoroughly to litter, walls, ceilings, floors, roosts, nests, and adjacent areas. Force spray into all cracks and crevices.
		malathion 57% EC	2 fl oz/gal water. Use 1 gal/1,000 sq ft.	0 days. Apply liberally to litter, walls, ceilings, floors, roosts, nests, and adjacent areas. Force spray into cracks and crevices.
		Rabon 50% WP (stirofos)	0.5 lb/6 gal water. Use 1-2 gal/1,000 sq ft.	0 days. Apply thoroughly to litter, walls, roosts, cracks, crevices, and interiors.
		Sevin 50% WP or 80% SP (carbaryl)	2 lb 50% WP or 1.5 lb 80% SP/5 gal water. Use 1-2 gal/1,000 sq ft.	7 days. Apply spray to walls, bedding, litter, and roosts. Force spray into cracks and crevices. Repeat as needed. Avoid contamination of nests, eggs, feed, and water.
	Dust	malathion 4-5%	1 lb/50-60 sq ft.	0 days. Apply liberally to litter, walls, ceilings, roosts, nests, and adjacent areas.
		Rabon 3% D or 50% WP (stirofos)	1 lb 3% D or 2.5 oz 50% WP/100 sq ft.	0 days. Treat litter evenly and thoroughly.
		Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Apply to litter, roosts, and adjacent areas. Do not apply to eggs or nests. Do not treat more than once every 4 weeks.
DARKLING BEETLES (LESSER MEALWORMS) Cream-colored larvae infest decaying organic matter or moldy feeds. Can serve as intermediate hosts for poultry pathogens. Sometimes nest in and damage building insulation.	Spray	Rabon 50% WP (stirofos)	2 lb/25 gal water. Use 1-2 gal/1,000 sq ft.	0 days. Apply evenly and thoroughly to litter, walls, center posts, and foundation walls.
		Sevin 80% SP or 40% or 43.4% suspensions (carbaryl)	62.5 lb 80% SP or 50 qt 40% or 43.4% suspensions/100 gal water. Use 2 gal/1,000 sq ft.	7 days. Apply evenly and thoroughly to litter or floor surface. Do not appy directly to poultry, nests, or eggs. Repeat as needed.
	Dust	Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Do not apply to eggs or nest litter. Do not treat more than once every 4 weeks.
		(Additional dusts registered to control mealworms include Safecide (boric acid), Littershield (stirofos plus diatomaceous earth), and Red Zone. See product labels for application methods and rates.)		
BED BUGS Flat, reddish brown, blood-sucking insects that feed at night. Rarely seen on birds during daylight.	Spray	Sevin 50% WP, 80% SP, or 40% or 43.4% suspensions (carbaryl)	8 lb 50% WP, 5 lb 80% SP, or 4 qt 40% or 43.4% suspensions/100 gal water. Use 1-2 gal/1,000 sq ft.	7 days. Apply thoroughly to walls, litter, and roost surfaces. Force spray into cracks and crevices. Do not apply directly to poultry, nests, or eggs. Repeat as needed.
	Dust	Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Apply even to litter. Do not treat more than once every 4 weeks. Do not apply to eggs or nest.

Horses

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
MANGE MITES Burrowing in skin causes pain and itching. Most prevalent in winter.	Spray	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of mites on horses. Check product labels for dilution and application rates.)		

Horses, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
LICE $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. Biting lice are yellow to red. Sucking lice are brownish to blue-gray. Head and neck, withers, and tailhead develop a scurfy appearance. Rubbing may create raw areas.	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	0.5 lb 25% WP or 1 pt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of lice on horses. Check product labels for dilution and application rates.)		
		malathion 57% EC or 25% WP	6.5-10 fl oz 57% EC or 0.75 lb 25% WP/5 gal water. Treat animal thoroughly.	0 days.
TICKS Seldom a problem unless horses graze in brushy or wooded areas.	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	1 lb 25% WP or 1 qt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days. Repeat as necessary.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of ticks on horses. Check product labels for dilution and application rates.)		
		malathion 57% EC or 25% WP	6.5-10 fl oz 57% EC or 0.75 lb 25% WP/5 gal water. Treat animal thoroughly.	0 days.
HORSE BOTS Flies are nearly as large as honey bees. They deposit eggs on the forelegs, throat, or muzzle, area; fly activity severely annoys horses. Eggs are ingested; larvae (bots) develop within the horse's alimentary canal.	Feed additive	Anthon 90% Powder (trichlorfon)	5 g/250 lb body weight mixed with feed. Treat from mid-October to mid-December.	Nonfood use. Repeat after 3 to 4 months. Withdraw all feed 12-18 hours prior to and 3 hours after treatment. Do not treat colts under 4 months of age, mares in the last month of gestation, or horses to be used for food.
	Oral paste	Eqvalan 1.87% (ivermectin)	Ready to use. Follow directions on prefilled tube.	Nonfood use.
		Equibot or Combot (trichlorfon)	Ready to use. Follow directions on prefilled syringe.	Nonfood use.
	Stomach tube	Consult with a veterinarian for treatment with carbon disulfide, or piperazine + carbon disulfide (Parvex Plus).		
	Preventive spray	malathion 57% EC	During fall months, sponge legs, under jaw, and chest of animal with a warm 0.5% malathion solution.	0 days. Eggs will be stimulated to hatch and the larvae will be prevented from borrowing into the animal. Re-treat when more eggs accumulate. Do not use bare hands; use specially prepared gloves or rubber gloves.
SCREWWORMS, BLOW FLIES Maggots develop in wounds.	Spray	Co-Ral 25% WP (coumaphos)	1.3 oz/gal water. Treat wound lightly but thoroughly.	0 days.
		Co-Ral 3% Spray Foam (coumaphos)	Ready to use. Spray thoroughly so that foam completely covers wound.	0 days.
	Dust	Co-Ral 5% D (coumaphos)	Ready to use. Treat wound lightly but thoroughly.	0 days.

Horses, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
HORN FLIES, FACE FLIES, STABLE FLIES, HORSE FLIES, DEER FLIES, BLACK FLIES, MOSQUITOES	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	0.5 lb 25% WP or 1 pt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days.
		malathion 57% EC or 25% WP	6.5-10 fl oz 57% EC or 0.75-1.25 lb 25% WP/5 gal water. Treat animal thoroughly.	0 days.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1-2 qt/animal.	0 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectrin, Permaban, and Permectrin II are registered for the control of biting flies on horses. Check product labels for dilution and application rates.)		
		Ectrin 10% WDL (fenvalerate)	4 fl oz/3 gal water. Mist 8 fl oz spray per animal. Direct at face, head, shoulders, and legs.	Do not treat animals intended for slaughter.
		pyrethrin plus synergist	Ready to use.	0 days. Apply as a mist spray. Do not wet the hide. Repeat as needed.
		Rabon 1% Spray-n-Wipe (stirofos)	Apply 1-2 fl oz to flanks, belly, and back.	0 days.
	Dust	Co-Ral 1% D (coumaphos)	2 oz/animal.	0 days. Apply to the head, neck, shoulders, back, and tailhead. Repeat as needed.
		malathion 4% D	4 tbsp/animal.	0 days. Apply evenly along back line. Repeat at 10-14 day intervals.
	Wipe-on	Rabon 2% Gel Wipe-on (stirofos)	1-2 fl oz/animal.	0 days. Apply as directed every 2-3 days if needed.

FLY CONTROL IN LIVESTOCK BUILDINGS AND FEEDLOTS

Filth fly species that commonly inhabit livestock dwellings, feedlots, and nearby buildings include the house fly, stable fly, little house fly, and several blow fly species. These flies develop in a variety of moist, organic wastes including manure, spilled feed, decaying vegetation, and garbage. Common breeding sites are around feed bunks, at the edges of feeding floors, under fences, along stacks of hay or straw, in accumulations of manure, and in waste drainage areas.

Although stable flies are biting flies that take blood meals from cattle, horses, and hogs, most other flies associated with confined livestock are nuisance pests, not blood feeders. Neither stable flies nor nonbiting nuisance flies spend much time on their animal hosts, so successful fly control around confined livestock does not center on animal treatments. The use of dust bags, oilers, or ear tags provides little or no control of flies in or around buildings. Sprays directed to the legs and belly of cattle, horses, and hogs (apply as recommended in preceding sections for horn fly control on individual livestock species) may provide short-term relief from stable fly attack, but such applications are not likely to significantly reduce the overall fly problem.

Thorough sanitation is the most important step in successful fly control. Weekly removal of manure, decaying hay and straw, and spilled feeds disrupts fly breeding sites frequently enough to prevent the development of fly larvae. Removing wastes beneath feeders and along fences is especially important. If manure is composted or temporarily piled before spreading, cover it with black plastic to prevent flies from entering or leaving this potential breeding site. If manure is not removed weekly, leaving an 8-inch-thick manure residue at each cleanup may help to maintain populations of insect predators and parasites that limit fly populations. Poultry producers who do not remove manure weekly can maintain predator and parasite populations by removing manure from beneath only one row of cages at each cleanup.

Insecticide applications may be necessary in addition to good sanitation. Unless otherwise indicated, premise treatments listed below can be used in beef, dairy (other than milking rooms), swine, sheep, goat, poultry, and horse facilities. Separate recommendations for fly control in milking rooms are provided.

Fly Control

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
HOUSE FLIES, STABLE FLIES, BLOW FLIES, ETC.	Space spray from mist blower or fogger	To minimize control failures caused by insecticide resistance, do not apply a single insecticide repeatedly throughout an entire season. Alternate applications of pyrethroids (permethrin products) and an organophosphate (naled). Space sprays (aerosols) provide rapid control of adult flies present at the time of application. Close doors and windows to reduce air movement during treatment. Daily to twice-weekly applications may be necessary where space sprays are the only treatments used. Animals may be present during application, but space sprays should not be applied directly to livestock. Do not apply space sprays in areas where animals have been treated directly with an insecticide during the previous 24 hours. Do not contaminate feed or water or use in milking rooms.		
		Dibrom 36% EC or 1% Ready-to-use Spray (naled)	1 qt 36% EC/40 gal water. Apply throughout building. Use 1 fl oz of 1% Ready-to-use Spray/ 3,000 cu ft.	0 days.
		Ectiban 5.7% EC (permethrin)	*Misting:* Use 4 fl oz/1,000 cu ft. *Overhead system:* 1 qt/12.5 gal fuel or mineral oil; use 4 fl oz/1,000 cu ft.	0 days.
		Permectrin II 10% EC (permethrin)	*Misting:* Use 4 fl oz/1,000 sq ft. *Overhead system:* 1 qt/12.5 gal fuel or mineral oil; use 4 fl oz/1,000 cu ft.	0 days.
		pyrethrins plus synergist	Follow label directions.	0 days.
	Surface residual spray	To minimize control failures caused by insecticide resistance, do not apply a single insecticide repeatedly throughout an entire season. Alternate applications of pyrethroids (permethrin, fenvalerate) and organophosphates (fenthion, dimethoate, stirofos). Surface sprays applied to walls, ceilings, partitions, posts, etc. kill flies at their resting sites and provide residual activity for 1-7 weeks. Products (or the listed concentrations of these products) recommended for use as residual sprays should not be applied directly to animals. Thoroughly spray surfaces to the point of runoff. Do not contaminate feed or water, and do not use residual sprays in milking rooms.		
		Baytex 45% EC (fenthion)	3 qt/25 gal water. use 1 gal/500 sq ft.	0 days. Residue persists 3-5 weeks.
		Cygon 23.4% EC (dimethoate)	1 gal/25 gal water. Use 1-2 gal/1,000 sq ft.	0 days. Remove all animals before spraying. Keep them out for at least 4 hours. Do not use in dairy barns or poultry houses. Residue persists 2-4 weeks.
		Ectiban 25% WP or 5.7% EC (permethrin) (Atroban, Insectrin, Expar, Overtime, Permaban, and Permectrin II are other permethrin products registered for use as surface residual sprays.)	6 oz 25% WP/11 gal water or 1 qt 5.7% EC/12.5 gal water. Use 1 gal/750 sq ft.	0 days. Residue persists 3-7 weeks.
		(Pounce is another permethrin product that can be used as a residual spray. It is classified for restricted use; do not apply Pounce directly to poultry or livestock.)		

Fly Control, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
HOUSE FLIES, STABLE FLIES, BLOW FLIES, ETC., cont.	Surface residual spray, cont.	Ectrin 10% WDL (fenvalerate)	1 qt/10 gal water. Use 1 gal/750 sq ft.	0 days for swine buildings. Use only in swine buildings and in horse barns where horses are not to be slaughtered. Residue persists 3-7 weeks.
		Rabon 50% WP (stirofos)	4-8 lb/25 gal water. Use 1-2 gal/1,000 sq ft.	0 days. Residue persists 2-4 weeks.
	Bait	Baits may enhance house fly control; they do not attract stable flies. Bait applications of insecticides used in surface residual sprays can be prepared by adding sugar or corn syrup to the spray tank mixture. Follow directions on individual product labels. Dry baits can be sprinkled in areas where flies congregate. Do not place dry baits in areas where birds or animals will contact the bait. Do not contaminate feed or water.		
		Dipterex 1% Dry Bait (trichlorfon)	4 oz/1,000 sq ft.	0 days.
		Golden Malrin 1% Dry Bait (methomyl)	4 oz/1,000 sq ft.	0 days.
	Manure spray	Manure sprays control fly larvae that are developing in treated feces. Migration of adult flies from nearby areas can occur if any breeding sites remain untreated. Manure sprays are recommended only where manure cannot be removed on a weekly basis. Apply sprays at rates that wet the manure surface; soaking is not necessary. Repeat applications as necessary, but not more often than every 7 days. Do not apply where mammals or birds will come in contact with the manure. Do not apply treated manure to crops not listed on the insecticide label.		
		Cygon 23.4% EC (dimethoate)	0.5 pt/5 qt water. Apply as a coarse spray.	0 days.
		Larvadex 5% SC (cyromazine)	1 qt/25 gal water. Use 1 gal/100 sq ft manure, pit, or lagoon surface.	0 days.
		Rabon 50% WP or 24% EC (stirofos)	4 lb 50% WP or 1 gal 24% EC/25 gal water. Use 1 gal/100 sq ft manure.	0 days.
	Feed additive	Feed additives used to prevent the development of fly larvae in feces provide minimal control of flies in livestock buildings. Feed additives do not reach house fly and stable fly larvae that develop in sites other than fresh manure. Good sanitation more effectively prohibits larval development. Animals must consistently consume recommended dosages for feed additives to be effective against fly larvae in manure.		
		Larvadex 0.3% Premix (cyromazine)	1 lb/ton of feed. Mix thoroughly.	Poultry only. Feed to laying hens only; not for broilers or poultry producing eggs for hatching purposes. Continuous use of cyromazine has led to fly resistance in research trials.
		Moorman's 0.02% IGR (methoprene)	0.25-0.5 lb/100 lb body weight/animal/month.	0 days. Feed mineral mix or block from May through September. Beef cattle and dairy cattle only.
		Rabon 7.76% or 97.3% Oral Larvacide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Use from May through September. Mix with complete feeds, concentrates, or protein supplements. For beef cattle, dairy cattle, or hogs only.

Fly Control, continued

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
HOUSE FLIES, STABLE FLIES, BLOW FLIES, ETC., cont.	Biological agents	Several companies sell parasitic wasps for use in controlling flies around livestock buildings and feedlots. These predaceous wasps attack only flies; they do not sting (or bite) other insects, animals, or humans. Adult wasps (less than 1/10 inch long) deposit eggs on or inside fly larvae or pupae. Developing wasps kill the immature flies. Suppliers usually recommend wasp releases (several thousand wasps per release) before and during the fly season. Most biological control programs recommend periodic (but not complete) removal of manure, effective water management, and control of weeds around feedlots and buildings. Some suppliers also recommend certain insecticide applications to supplement the control provided by biological agents. In many instances it is difficult to assess the separate impacts of parasitic wasps, sanitation practices, and insecticide applications. Although wasp releases have been shown to be effective for fly control in certain poultry housing, research data do not support other uses of currently available biological controls for flies. If biological control agents are to significantly contribute to fly control programs, integration with sanitation and chemical control practices is essential.		
CONTROL OF FLIES IN MILKING ROOMS	Although effective fly control is essential in dairy barns and milkrooms, small amounts of pesticides can be detected in milk, and their presence is often illegal. To control flies and avoid residue problems, the following steps are recommended: 1. Use good sanitation and recommended insecticides in dairy barns to reduce the number of flies entering the milkroom. 2. Use sticky fly strips where appropriate. 3. Use tight screens (14-16 mesh) on milkroom doors and windows. Copper, aluminum, bronze, plastic, or rust-resisting screens are best. 4. Use a mist or aerosol spray of 0.06-0.1% pyrethrin plus piperonyl butoxide oil-based fly sprays in the milkroom when other methods do not give adequate fly control. To prevent milk contamination, cover all milking utensils, cans, bulk tanks, and containers before spraying.			
RATTAILED MAGGOTS	The rattailed maggot is the larval stage of a syrphid fly. The 1¼ inch long maggot has a cylindrical body about ¾ inch long and a tail-like breathing tube that extends ½ inch from the posterior of the body. The adult fly is a beelike hover fly that is not a pest on or around livestock or humans. Rattailed maggots live in highly polluted water such as that in livestock lagoons and manure pits. When larvae are ready to pupate, they migrate from lagoons and pits to adjacent, drier areas. They become pests when they enter feed, egg cartons, and milking rooms. To limit rattailed maggot development, eliminate floating solids within pits and keep pit sidewalls clean. Agitate the pit contents or pump the pit weekly. Although insecticides are of limited value in managing rattailed maggots, application of Ravap or Larvadex to the pit surface provides some control. Use 1 pint Ravap 28.7% EC per 3½ gallons fuel oil and apply 1 gallon of the spray mixture per 100 square feet of pit surface. (Do not agitate the pit contents after application.) Repeat applications as needed, but not more often than every 7 days. Use 1 quart Larvadex 5% SC per 25 gallons water and apply ½ to 1 gallon of finished spray per 100 square feet of pit surface. Limit rattailed maggot migration by constructing a soil barrier between the pit and the milking room. Migrating larvae will burrow into the loose soil to pupate instead of continuing their migration into milking rooms, etc.			

Diatomaceous earth. The insecticidal activity of a range of chemically inert dusts, including diatomaceous earth, results from their abrasiveness and/or their sorptive characteristics. To understand how these dusts kill insects, it is important to recognize that an insect's body covering, the cuticle, contains fat layers that make the cuticle nearly water-proof and prevent water loss. Sorptive dusts absorb fats, disrupting the cuticle's waterproof nature. Abrasive dusts damage the insect's water barrier by actually scratching or cutting the cuticle. Where inert dusts are effective as insecticides, dehydration usually causes the insect's death.

For animal ectoparasite control, sorptive and/or abrasive dusts have been used somewhat successfully for reducing populations of lice, fleas, and some mites on a range of animal species and humans. Although most trials have evaluated silica aerogels, diatomaceous earth was used effectively to control cattle-biting lice in a study conducted in the 1930s. Silica aerogels were used at a rate of 1 to 2 ounces of dust per cow; diatomaceous earth was applied at a rate of 3 ounces per cow. Based on available evidence, it is likely that although diatomaceous earth will not work as well as currently available chemical insecticides, if applied thoroughly and repeatedly, it should provide some control of lice, fleas, and certain mites. Because of the skin-burrowing habits of swine mange mites, producers should not expect diatomaceous earth to control this pest.

Advertisements claim that diatomaceous earth used as a feed additive will provide control of internal parasites and also control fly larvae in animal manure. Sales materials also include claims of controlling adult flies by aerosol, dust bag, or hand-dusting applications of diatomaceous earth to barns and animals. No reliable data support these claims of fly control. Negative data and an understanding of fly breeding and migration lead to the conclusion that little or no fly control is likely to be achieved by using diatomaceous earth.

1990 Insect Pest Management Guide

FIELD and FORAGE CROPS

Intent of This Publication

This publication addresses pest management guidelines and alternatives for insects that attack field and forage crops in Illinois. Where practical, **nonchemical control** measures that have proven effective are discussed and strongly encouraged. However, **insecticides** are frequently the only and most efficient tool for responding to insect pest outbreaks. We recommend that insecticides be used only to supplement a completely **integrated pest management (IPM)** program that also includes the use of cultural, mechanical, and biological control tactics.

IPM has been defined as the selection of management practices that promote favorable economic, ecological, and sociological outcomes. In this context, insecticides should be used only after all other effective insect control alternatives have been explored. Furthermore, insecticides should be used only when an insect population has reached or exceeded an **economic threshold** — that level of a pest population when control should be implemented to prevent economic yield loss (projected cost of damage is greater than the cost of control). Then, before one makes a decision to use an insecticide, potential **risks and benefits** should be evaluated. Risks to human health and safety, as well as environmental risks, such as the potential for surface or groundwater contamination and wildlife destruction, should be carefully considered along with the economic benefits of insect control with insecticides.

The insect management practices that are discussed in this publication are based on research results from the Illinois Natural History Survey, the University of Illinois College of Agriculture, other land-grant universities, and the United States Department of Agriculture. Insecticides suggested for use have been registered by the U.S. Environmental Protection Agency (EPA). The information within this publication is revised annually and is intended for use during the current calendar year only.

Contents

Prepared by Kevin L. Steffey and Michael E. Gray, Extension Entomologists

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
In cooperation with ILLINOIS NATURAL HISTORY SURVEY CIRCULAR 899-90 (revised annually) October 1989

Information Resources

Information about publications and educational meetings dealing with insect management in field and forage crops is available from your county Extension office or from Extension Entomology, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820; telephone (217)333-6652.

Insect Fact Sheets

Fact sheets (designated by NHE numbers) that discuss nonchemical control methods and give descriptions of specific insects and their life history and biology have been prepared for most of the insects that attack field and forage crops in Illinois. Color picture sheets are also available in this series. Individual fact sheets and color picture sheets are $.25 each.

Insect Pest Management Guides

Other insect pest management guides available are Circular 897, *Insect Pest Management Guide: Commercial Vegetable Crops;* Circular 898, *Insect Pest Management Guide: Livestock and Livestock Buildings;* Circular 900, *Insect Pest Management Guide: Home, Yard, and Garden;* and Circular 1242, *Insect Pest Management Guide: Stored Grain.* Copies of these circulars are available from the Office of Agricultural Publications, address below.

Illinois Pest Control Handbook

All of the above-mentioned circulars, other references regarding management of insects, weeds, plant diseases, and vertebrate pests (including rats and mice), and pesticide application guidelines are bound together annually in the *Illinois Pest Control Handbook.* This is a valuable reference for pesticide dealers and applicators, farm managers, and anyone who frequently must answer questions about pest control. This publication can be obtained from the Office of Agricultural Publications, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois, 61801; telephone (217)333-2007.

Field Crop Scouting Manual

The *Field Crop Scouting Manual* contains information relating to disease, insect, and weed identification, scouting techniques, and economic thresholds. A section on alfalfa insects has been added to the revised edition, as well as identification keys for seedling broadleaves and grasses. Picture sheets and line drawings are provided for many diseases, insects, and weeds that affect field crop production. Corn and soybean management guides that will assist crop consultants in diagnosing pest problems throughout the growing season are also provided.

Insect Management Alternatives

The series "Alternatives in Insect Management" (Circular 1295, *Alternatives in Insect Management: Microbial Insects,* and Circular 1296, *Alternatives in Insect Management: Botanical Insecticides and Insecticidal Soaps*) describes insect control methods that do not involve conventional insecticides. While synthetic chemical insecticides provide many benefits to food production and human health, they also pose some hazards. In many instances, alternative methods adequately control insects and pose fewer hazards. The publications in this series discuss the characteristics and relative strengths and weaknesses of available alternatives. This series of publications is available from the Office of Agricultural Publications (see address and telephone listed previously).

Insect, Weed, and Plant Disease Survey Newsletter

The *Insect, Weed, and Plant Disease Survey Bulletin* is issued weekly from April through August. This series of newsletters provides a timely look at the agricultural insect, weed, and plant disease situation, along with suggested control measures. New developments in pesticide application are also included. To subscribe to this valuable newsletter, contact the Agricultural Newsletter Service, 116 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801; telephone (217) 333-2666.

Illinois Agricultural Pesticides Conference

The Illinois Agricultural Pesticides Conference is held annually in early January on the campus of the University of Illinois. The conference deals with current issues surrounding the use of agricultural pesticides and encourages the proper, timely, and wise use of pesticides within an integrated crop management system. It is a public meeting for anyone in agriculture who has an interest in using pesticides in a crop pest management program.

Printed proceedings from this conference are available from Extension Entomology (see address and telephone listed previously). This 200-page reference contains about 40 articles concerning recent research information about insect, weed, and plant disease management and about recent advances in pesticide application technology.

Sixteenth Annual Illinois Crop Protection Workshop

The Illinois Crop Protection Workshop is an annual program (March 13 to 15 in 1990) that provides the latest crop management information to agronomists, agrichemical representatives, county Extension advisers, crop consultants, farmers, farm managers, pesticide dealers and applicators, seed company representatives, soil conservationists, and anyone who has an interest in agricultural and environmental issues. Specialists provide in-depth discussions, educational materials, and "hands-on" exercises in specialized sessions regarding the biology and pest management strategies for insect, weed, and disease problems that occur in Illinois crops. General sessions provide challenging and far-ranging topics that affect a large cross-section of those involved in agriculture.

Field Crop Pest Management Short Course

The Field Crop Pest Management Short Course is an annual program (March 19 to 21 in 1990) designed to train personnel that will be monitoring field crops for diseases, insects, and weeds. The latest scouting procedures and field sampling techniques are discussed by specialists from each of the pest management disciplines. Pest identification, plant injury symptoms, and economic thresholds are discussed in detail in a laboratory setting. A general session provides information on nutrient deficiency problems, as well as a discussion on the growth and development of corn and soybeans. All participants who successfully complete the short course receive a certificate of achievement.

Pesticide Applicator Training Clinics

Commercial pesticide applicator training and certification clinics are offered annually at several locations throughout Illinois. Training for the General Standards exam and several commercial applicator categories are offered for applicators seeking to become certified. University of Illinois personnel provide the training and updates, and representatives from the Illinois Department of Agriculture oversee the testing. Study guides for the General Standards category and most of the commercial applicator categories are available at each clinic and through the county Extension offices or Extension Entomology. Contact Extension Entomology (see address and telephone listed previously) for information about dates, times, and locations for the various clinics.

Decision-Making for Insect Management

In order to successfully manage an insect population affecting a field crop, one must make many decisions. These decisions should reflect the long-term interests of the producer and the environment and may be very complex. Populations of insects (both beneficial and damaging species), weeds, and plant diseases interact with the crop and the abiotic (nonliving) component of the environment. When one also considers the bewildering complexity of crop production practices such as tillage, crop rotation, use of cover crops, crop variety, and type of fertility program, careful planning and considerable information are necessary to understand how a decision may influence a pest outbreak.

Integrated Pest Management

Weeds, plant diseases, and certain insects are pests because they compete with humans for food and fiber. The term "pest" is a label given to these competing organisms, but it has no ecological significance. Although the routine use of pesticides has become a standard practice for reducing pest populations, certain problems arise from a sole reliance on pesticides. Because of growing concerns regarding insecticide resistance, secondary pest resurgence, and threats to public health in the 1960s and 1970s, the philosophy of integrated pest management (IPM) originated. In the 1980s, concerns over groundwater contamination and pesticide residue levels in food continue to emphasize the need for judicious use of pesticides. More than ever, IPM methodologies are vital for a sustainable national agricultural program and for environmental protection.

Insect populations in field crops react to the same fundamental ecological principles that influence interactions of plants and animals in natural ecosystems. Agroecosystems have much less diversity of species (beneficial organisms, plants, and pests) than occurs in a forest or a prairie. Consequently, a field crop is more susceptible to a pest outbreak because of this lack of plant and animal variety. The quick and often unpredictable alterations inflicted by changing weather and crop production practices can also trigger a sudden increase in a pest's population.

IPM programs promote favorable economic, ecological, and sociological outcomes. In order to accomplish this challenging goal, agricultural scientists have attempted to modify the life systems of insects, weeds, and diseases. As the term "integrated" implies, this objective is accomplished best by blending pest control tactics. The following cultural methods are often components of a successful IPM program: (1) use of resistant crop varieties, (2) crop rotation, (3) changing tillage practices, (4) variation of planting or harvest dates, (5) proper fertilization, (6) proper sanitation, and (7) use of trap crops. In addition to these cultural tactics, other pest management techniques such as biological control, genetic manipulation of pests, and the use of pesticides can be interwoven effectively into a complete program.

Economic Thresholds

In order to effectively manage an insect population, one must thoroughly understand the insect's life cycle and biology, as well as its potential to cause economic loss. People who attempt to put this knowledge to use by reducing an insect's population below a certain threshold are practicing an applied ecological approach.

The use of appropriate scouting tactics, proper identification of pests, and the use of thresholds are fundamental components of a sound IPM program. The economic threshold (ET) is that level of an insect population that indicates that control tactics should be used to stop a pest population from increasing further, thereby preventing economic losses. Economic thresholds may be expressed as numbers of insects — average number of potato leafhoppers per sweep in an alfalfa field — or as a level of damage — 5 to 10 percent of soybean pods injured within a field. The population level of a pest that is sufficiently high to cause economic damage to a crop is referred to as the economic injury level. The economic threshold is often referred to as the "action threshold" because control measures are usually employed when the insect population reaches this level to prevent the pest population from reaching the economic injury level.

Many years of research are required before carefully defined economic thresholds can be developed. Most currently used thresholds are simplistic and do not incorporate multiple pest densities into the decision-making process. More comprehensive economic thresholds should incorporate multiple pest densities, abiotic plant stresses (moisture stress, nutritional deficiencies, compaction, etc.), and unique agronomic practices into the decision-making process.

Neither environmental nor economical conditions are stable, and several factors may alter an economic threshold: (1) value of the crop (as the price paid for the crop increases, the economic threshold decreases), (2) cost of control (as the cost of control increases, the economic threshold also increases), and (3) crop stress (as the amount of stress on a crop increases, the economic threshold may decrease). For example, an insecticide may be economically justified for an insect pest population below the economic threshold if the crop is under stress from a lack of moisture, severe weed pressure, a plant disease, or a lack of proper fertility. Economic thresholds should be adjusted to comply with changes in market prices, cost of control, and the level of stress the crop is experiencing.

The use of an economic threshold and an economic injury level assumes that some knowledge of the average population density of an insect over time is known. Many insects are not pests. Populations of these insects in cultivated crops never reach a level sufficiently high to cause an economic loss. Occasional pests may reach the economic injury level when environmental conditions are favorable for an increase in the insect's density. For example, hot and dry weather favors outbreaks of spider mite populations during the growing season. Other insect populations are perennial, that is, their economic injury level is not much above their average population density. Certain agricultural pests fall into this category and, therefore, require carefully designed integrated management programs to keep their levels below the economic injury level.

Although much research is required before carefully defined comprehensive economic thresholds can be developed, producers should not be discouraged from beginning an IPM program. Comprehensive economic thresholds need not be available before progress can be made. More realistically, simple action thresholds can at least serve as starting points for an IPM program. Knowledge of these commonly used simple economic thresholds will likely prevent many needless applications of pesticides.

Field Scouting

The use of economic thresholds requires that fields be monitored for insect populations, both beneficial and potentially harmful species. A successful pest management program hinges on these population estimates. Recognizing various pests and their damage is becoming increasingly important from an economic and environmental perspective. Pest scouting has been accepted by many Illinois farmers, and scouting programs are currently offered by private consulting firms, farmer cooperatives, pesticide dealers, and seed companies throughout the state.

The following questions should be considered by a producer when he or she is thinking about a scouting program or hiring a crop consultant: (1) Do you have the time to scout?; (2) Do you know how and when to scout?; (3) Can you identify insect pests?; (4) Can you identify beneficial insects?; (5) Can you accurately sample insect populations, at least well enough to feel comfortable with your decisions?; (6) Can you accurately measure crop damage?; (7) Do you know and understand economic thresholds?; (8) Do you know all of the insect-control alternatives?; and (9) Can you prepare a thorough set of crop scouting records? If a producer answers "no" to most of these questions and would like to begin an active IPM program, the services of a professional crop consultant should be considered. By enrolling in numerous IPM educational programs offered by the Cooperative Extension Service, producers can soon learn the latest crop monitoring techniques and begin scouting their own fields.

Tillage and Crop Rotation

Tillage practices may have direct or indirect effects on soil organisms. Type of equipment, timing (fall or spring), depth, and frequency of tillage operations are variables that can dramatically influence the survival of some insect species. An insect's unique reaction to changes in soil temperature, soil moisture, aeration, organic matter content, and bulk density of the soil may be regarded as direct effects on an insect's survival. Often of greater importance to an insect population are the indirect effects occasionally associated with certain tillage systems. For example, poor weed management practices in some tillage systems increase specific insect populations (black cutworms, stalk borers). However, it is not appropriate to make sweeping predictions about how all insects are likely to respond to a certain tillage practice. Insect biologies vary among species, as do their responses to various tillage practices, rotations, and cover crops.

Crop rotation greatly influences whether a soil insect problem may occur. The complex of insect pests will change according to the type of crops rotated, sequence of the crop rotation, and the amount of time devoted to the production of a particular crop prior to the planting of a new crop. The brief summaries that follow are designed to aid the producer in the decision-making process concerning the likelihood of an insect outbreak based upon the crop rotation used.

Corn after grass sod. Corn billbugs, sod webworms, white grubs, and wireworms may cause stand reductions when corn follows bluegrass, brome, fescue, rye, or wheat. If a producer decides to plant corn into an established field of grass sod, an insecticide at planting should be considered for the control of wireworms and white grubs because rescue treatments are not effective. If a stand is being seriously thinned by wireworms or white grubs, the only option is to replant and apply an insecticide during the replanting operation.

Corn after soybeans. The potential for soil insect problems in corn after soybeans is generally low, and the use of a soil insecticide is not recommended. A lindane or diazinon + lindane planter-box seed treatment will be adequate to protect the seeds against seedcorn beetles, seedcorn maggots, and wireworms.

Corn after corn. The potential for rootworm damage is moderate to severe wherever corn follows corn in Illinois. A rootworm soil insecticide may be needed in fields of corn after corn.

Corn after sorghum. A planter-box seed treatment of diazinon or diazinon + lindane will protect the seeds against seedcorn maggots.

Corn after small grain. There is a slight potential for damage by wireworms, seedcorn beetles, and seedcorn maggots in corn after small grain, particularly wheat. In most instances, a diazinon + lindane planter-box seed treatment is adequate. Excessive weed cover in small-grain stubble may have been attractive to northern corn rootworm beetles for egg-laying as the beetles moved from adjacent fields of drought-stressed corn.

Corn after legumes. Cutworms, grape colaspis, white grubs, and wireworms occasionally damage corn planted after clover and alfalfa. In addition, adult northern corn rootworms are sometimes attracted to legumes or to weed blossoms in legumes for egg-laying, especially in years when beetles are forced to leave adjacent fields of drouth-stressed corn to seek food. The use of a seed treatment is recommended, but producers may consider the use of a soil insecticide for this cropping sequence.

By comparison with research efforts on corn insects, much less research has focused on the influence of various cultural practices on soybean insect populations.

Most soybean insect pests are defoliators or pod feeders. These insects are often very mobile; some immigrate from other regions, and most move readily from field to field. The influence of a single soybean producer's unique tillage practices has often been viewed as insignificant in terms of increasing or decreasing the likelihood of pest damage caused by defoliators. Recently more research has been directed toward evaluating the potential effect of various tillage practices, crop rotational schemes, and cover crops on insect populations affecting soybean production. As results from many of these experiments are examined, it is obvious that the use of cover crops, tillage, and rotational sequences have different effects on many species of soybean insect pests.

Preventive and Rescue Insecticide Applications

After a thorough consideration of various IPM tactics, field scouting techniques, economic thresholds, and estimates of the likelihood of an insect outbreak, a producer must weigh the benefits of a preventive insecticide application against a "rescue" treatment. Each year a farmer must estimate the potential for insect pests to cause economic loss before deciding whether to apply an insecticide. If the odds are very high that a certain insect has the potential to cause an economic loss in most years, a producer is likely to use a preventive insecticide application. The following are some key factors that a grower must assess in determining the probability of an insect outbreak: (1) crop rotation; (2) nature of insect problems over the years (perennial or occasional); (3) type and timing of tillage practices; (4) density of overwintering insect population; (5) density of spring weed populations and, for certain insect pests, the fall population of weeds; and (6) weather.

If the decision to use a preventive insecticide application is made by the producer, several questions should be pondered very carefully.

- Is the insect you want to control listed on the insecticide label?
- Does the label suggest that the insecticide will control the insect, or do the phrases "suppression" or "will control low to moderate populations" appear?
- Will the insecticide selected provide acceptable control of the insect? Are you familiar with university research and recommendations?
- Is the recommended rate of application economical for your operation?
- Where should you place (band, furrow, broadcast) the insecticide to control the insect?
- How toxic is the insecticide? Is it a restricted-use insecticide?
- Should you use a granular or liquid formulation?
- Will the insecticide pose any potential hazards to the environment? If so, are there any better alternatives?

Many producers continue to rely very successfully on "rescue" insecticide treatments for certain insect pests as part of their overall farm management program. This approach has worked very well with black cutworms throughout the state of Illinois. Producers are made aware of the intensity of black cutworm moth flights in their counties and are provided with good scouting information and economic thresholds. If cutworms reach damaging levels, insecticides can be used as postemergence treatments.

Nonchemical Control Alternatives

When making a decision regarding how to effectively manage an insect population, growers are encouraged to examine nonchemical approaches. What are these alternative approaches, and how available are they?

Through a process referred to as "natural control," certain insects and diseases suppress populations of pest insects without our help. For example, European corn borer populations are often reduced by *Beauveria bassiana,* a fungus, or by *Nosema pyrausta,* a protozoan. These diseases are part of the natural ecosystem and exert their influence without human intervention. Through a process more appropriately called "applied biological control," predators, parasites, or disease pathogens are introduced into the agroecosystem artificially. Although much research has been conducted, the introduction of beneficial insects and disease pathogens into corn and soybean fields to control pest insects has not fared well. These environments are constantly changing, so beneficial organisms have a difficult time becoming established. Success stories in applied biological control are most often associated with more stable environments like forests. This is not to say that we shouldn't continue to explore and conduct research on promising opportunities for applied biological control in field crops. However, the practical implications of releasing predators, parasites, or insect pathogens have not been borne out in row crops in the Midwest.

The use of microbial insecticides currently offers considerably more potential within an IPM program. Microbial insecticides are made of microscopic living organisms (viruses, bacteria, fungi, protozoa, or nematodes) or the toxins produced by them. These insecticides can be formulated to be applied as sprays, dusts, or granules. The chief advantage that microbial insecticides offer is their extremely low toxicity to nontarget animals and humans. Dipel 10G and Dipel ES are different formulations of a microbial insecticide that contains spores and the crystalline endotoxin of the bacterium

Bacillus thuringiensis kurstaki (B.t.). Each of these formulations is registered and provides effective control of the European corn borer. B.t. products are effective only against the caterpillar stages of moths and butterflies. Because they have very low toxicity to most other organisms, B.t. products are very useful in the management of the European corn borer in fields where worker safety or the safety of people in residential areas is a prime concern. An example of where the use of B.t. products makes good sense is for seed fields where detasselers are working.

Many nonchemical alternatives in insect management often have been referred to as cultural approaches. These include the use of resistant crop varieties or trap crops, altering planting or harvesting dates, crop rotation, and the use of fly-free dates (listed by county in NHE-152) for seeding wheat to prevent infestations of Hessian flies. By practicing many of these suggested cultural approaches, Illinois farmers are currently reducing the amount of insecticides used to a great extent. By rotating corn with soybeans, producers eliminate the need for a soil insecticide on approximately 6 million acres of Illinois farmland each year. The importance of this nonchemical approach to insect management is often overlooked.

It must be mentioned that after a producer has explored all of the pest management options, the decision not to treat should be recognized as a valid choice. Although economic factors are often the pivotal point on which a grower makes an insect control decision, farmers are becoming increasingly aware of environmental and societal concerns regarding their pest management considerations. Questions such as the following will be asked more frequently in the future: (1) Will this pesticide contaminate groundwater, even when normal labeled recommendations are followed?; (2) Will the use of this pesticide expose me or my family to any serious health and safety risks?; (3) Will the use of this product seriously reduce nontarget populations of other organisms?; and, (4) Will the use of this product at labeled rates show up as an unsafe residue in food products? A producer's decision not to use an insecticide because of his or her response to these or similar questions must be considered a valid one.

Insect Pests of Field and Forage Crops

Corn Insects

Armyworms

Armyworms damaged both corn and wheat during the spring of 1989. The outbreak was probably a result of the drought conditions of 1988 reducing the populations of natural enemies that usually hold armyworms in check. However, toward the end of June 1989, naturally occurring diseases killed many armyworms. Damaging levels of the later generation of armyworms did not materialize.

Armyworms do not overwinter in Illinois. Like the black cutworm, armyworm moths fly or are blown into Illinois on storm fronts early in the spring. The moths seek rank, grassy vegetation on which to deposit their eggs. Wheat and rye provide excellent egg-laying habitats. As a consequence, corn planted no-till into rye or some other grassy cover crop may experience severe damage by armyworm larvae. Cornfields adjacent to wheat fields are also at risk. If the larvae completely defoliate a wheat field or if the wheat field matures, armyworms may assume their gregarious marching habit and crawl into a nearby cornfield.

Upon hatching, armyworm larvae feed on grassy vegetation. However, when herbicides are used to control these grasses in no-till or very weedy cornfields, the larvae will move from the dying grass to feed on corn seedlings, usually chewing along the outer edges of the newly emerged leaves. If the armyworm population is large enough, the larvae may completely strip the corn plants. Corn usually recovers if the plants have not been damaged below the growing point. If the infestation is severe and plants are eaten below the growing point, entire stands of corn can be significantly reduced or even destroyed.

Control of the first generation of armyworms in seedling corn may be (justified when 25 percent of the plants are being defoliated. A second generation of armyworms occurs around pollen shed, but control is justified only when the armyworms have devoured all the leaves below the ear and are starting to defoliate the leaves above the ear.

Corn cutworms

The occurrence and extent of cutworm infestations are difficult to predict each year. ***Sandhill, dingy,*** and ***claybacked cutworms*** all overwinter in Illinois as partially grown larvae, but their populations are seldom widespread. As a result, they cause damage early in the growing season in scattered areas. Sandhill cutworms are a problem in sandy areas almost every year. Dingy and claybacked cutworms occur more frequently in corn planted after sod or forage legumes than in other crop rotations.

Black cutworms do not overwinter in Illinois, so outbreaks are difficult to forecast. Infestations of black cutworm larvae arise from eggs laid by moths that fly or are blown into Illinois on storm fronts in the early spring. A statewide program of monitoring black cutworm pheromone traps provides information about the time and intensity of spring moth flights.

Certain factors favor black cutworm outbreaks. The most important factors may be late planting and preplant weed infestations. Fields that are tilled and planted late are more likely to develop a preplant weed infestation than fields that are planted early. These late-planted fields with weeds are more attractive to cutworm moths as a site on which to deposit their eggs.

Currently, two options are available for cutworm control: applications of soil insecticides to prevent damage and rescue treatments after the infestation appears. **Because of the uncertainty in predicting which fields will have light, moderate, or heavy infestations of cutworms, it is advisable to use rescue treatments for cutworm outbreaks rather than to use a preplant or planting-time treatment unnecessarily.**

Based on the relatively low incidence of cutworm problems over the past 30 years, a grower should find an economic advantage to the wait-and-see system, which involves field scouting rather than a costly always-apply program in which the soil insecticide is routinely applied at or before planting for a problem that may not exist.

Rescue (or emergency) treatments. The keys to effective cutworm control with rescue treatments are the amount of surface moisture and the movement of the worms. Control may be poor, regardless of the insecticide used, if the topsoil is dry and crusted and the worms are working below the soil surface. When the soil is dry, the higher recommended rates of the insecticides should be considered.

To determine the need for rescue treatments, scout the fields during plant emergence, particularly those fields considered to be high-risk. Early detection of leaf-feeding or of cutting by cutworms is vital. When the corn plants are beginning to emerge, check the fields for leaf-feeding, cutting, wilting, or missing plants. Small cutworm larvae (less than ½ inch) feed on the leaves and do not begin cutting plants until they are about half-grown.

A control measure may be needed on corn if 3 percent or more of the plants are cut and cutworms are still present. A single cutworm will cut 3 or 4 plants if the plants are in the 2-leaf stage or smaller. After corn plants reach the 4-leaf stage, a single cutworm will cut only 1 or 2 plants during the remainder of its larval stage.

Corn leaf aphids

In the drier regions of Illinois in 1989, corn growers found rather large populations of corn leaf aphids. Although populations in individual fields were large, the outbreak was not widespread. However, their presence in moisture-stressed fields during pollination caused some yield reduction in both seed corn and field corn.

Corn leaf aphids do not overwinter in Illinois, relying instead on storm fronts in late June through early July to carry them to their destination. Corn leaf aphids are soft-bodied, have a bluish-green color, and are roughly the size of a pinhead. At the rear of these insects, two projections referred to as cornicles ("tail pipes") can be easily seen with a hand lens.

Aphids have piercing-sucking mouthparts with which they remove fluids from plant tissues. Their feeding injury to corn is most severe when the removal of fluids and sugars occurs during the pollination period and the crop is under moisture stress. In addition, the aphids secrete a sugary "honey dew" which often coats the tassels and interferes with pollen shed.

Corn leaf aphids have tremendous reproductive powers, and populations can seemingly explode in a very short time. Approximately nine generations of these aphids occur per year in Illinois. When aphid numbers begin to increase significantly, clusters will begin to show up on leaves and in the whorls of plants. As these clusters grow larger, winged females will become more numerous. These females fly away from heavily infested plants and move to other plants to begin new colonies.

Control may be warranted when 50 percent of the plants have light to moderate levels of aphids on the tassels and upper leaves, and the corn is suffering from a lack of moisture. Aphids can also lower yields soon after pollination is complete if 20 to 25 percent of the plants are heavily infested (upper leaves and tassel covered) and the corn is under moisture stress. Before a management decision is made, however, the number of predators and percentage of diseased aphids should be determined. Aphidlions and ladybird beetle larvae and adults are excellent predators of aphids. Parasitized aphids are smaller, hardened, brownish, and stuck to leaves or tassels. Diseased aphids are shriveled and moldy.

Corn rootworms

Populations of northern and western corn rootworm beetles were high in many areas of Illinois in 1989. However, environmental conditions and the condition of the corn crop varied significantly across the state, so the numbers of rootworm beetles also varied from region to region. Although the potential for rootworm damage to corn following corn is greatest in the northern two-thirds of the state, moderate to severe damage to corn roots by larvae may occur in any field where corn follows corn in Illinois.

Rootworm life cycle

Western and northern corn rootworm beetles deposit their eggs in the soil at the base of the corn plants or between rows during August and September. The eggs overwinter in the soil and begin hatching in late May. Egg hatch usually takes place over a period of 3 to 5 weeks. Consequently, in July and August all stages of the corn rootworm — egg, larva, pupa, and adult — may be found. The rootworm larvae feed on the roots of corn plants during June, July, and August. When a larva is fully grown (½ inch), it builds a cavity in the soil and goes into the pupal or resting stage. After 5 to 10 days, the beetle emerges from the soil. The development from egg hatch to adult emergence takes 27 to 40 days. After the females emerge from the soil and mate, 14 days or more elapse before they begin laying eggs. Rootworm beetles may deposit as many as 1,000 eggs; an average of 500 per female is probably common. Most egg-laying in Illinois occurs after August 1.

Extended diapause

Since 1986 in the northern half of Illinois, a small number of fields of corn following soybeans have been damaged by corn rootworm larvae. Entomologists have verified that the damage was caused by northern corn rootworms, some of which are known to undergo extended diapause (a period of suspended development) in the egg stage. Extended diapause is not known to occur in the western corn rootworm population, the predominant species of rootworms in Illinois.

Crop rotation and certain environmental conditions may favor the expression of extended diapause in northern corn rootworms, thereby enabling the eggs to survive two winters before hatching. Ordinarily rootworm eggs hatch the year after they are deposited.

Should a farmer use a corn rootworm soil insecticide on corn following soybeans to control corn rootworms in 1990? Although the answer is not a clear-cut "no," the percentage of cornfields following soybeans that have been economically damaged by corn rootworms has been extremely small. Based on a random survey of 990 fields of corn following soybeans in the northern half of Illinois, only 1 percent of the fields sampled from 1986-1989 had economic rootworm damage. At this point there is little justification for using a soil insecticide in corn following soybeans. A few fields may sustain damage in 1990, but it is impossible to predict where these will be.

What scenerio might best describe how corn rootworm damage to corn following soybeans might occur in 1990 as a consequence of extended diapause in the northern corn rootworm population? Northern corn rootworm beetle numbers had to exceed 2 beetles per plant in a field of corn during August 1988 in order to produce a sufficient number of diapausing eggs to cause larval damage to corn after soybeans in 1990. Research entomologists in Illinois are conducting investigations into the phenomenon of extended diapause within the northern corn rootworm populations to determine the extent of this trait in Illinois.

Determining potential for damage in 1990

Corn growers should base the need for using a rootworm soil insecticide in 1990 on the abundance of rootworm beetles in cornfields during late summer of 1989. Generally, if beetle numbers reached or exceeded 0.75 per plant at any time during late July, August, or September 1989, plan to apply a rootworm soil insecticide if the field is to be replanted to corn in 1990.

However, if the field scouted in 1989 was corn following any crop other than corn, the threshold (beetles per plant) is lower. The ratio of female to male beetles in first-year corn is usually higher than in continuous corn. The females apparently migrate into first-year cornfields, so most of the beetles found there are females. As a consequence, the threshold for determining whether to rotate away from corn or to use a soil insecticide in 1990 may be as low as 0.5 beetle per plant. (See "Scouting to Determine Rootworm Potential in 1991" for a discussion about adjusting thresholds for different plant populations.)

Fields of corn planted in late May or June 1989 may have extensive rootworm damage if replanted to corn in 1990. During August and September, rootworm beetles are especially attracted to late-planted or late-maturing fields. Seeking fresh pollen and silks to feed on, the beetles lay millions of eggs in these fields. Planting the fields to a crop other than corn in 1990 is suggested to reduce the rootworm population.

Suggestions for rootworm management, 1990

During the past 12 years, the performance of rootworm soil insecticides has been variable. They have provided effective control at some locations and have been marginal or ineffective at others. An immediate solution to the problem of erratic rootworm soil insecticide performance is not readily available. Perhaps there is none. It is entirely possible that changes brought about by treating millions of acres of corn with soil insecticides over the past 20 years have introduced an era when rootworm control with current soil insecticides will be highly variable.

Looking to 1990, you should seriously consider crop rotation, particularly in fields where there is a high probability of rootworm damage. Other alternatives include applications of a soil insecticide at planting or at cultivation. Planting time treatments of a soil insecticide will be the predominant method of rootworm control. However, a cultivator application in early June near the beginning of rootworm egg hatch can be an effective option. If you use a soil insecticide at planting, plan to check fields in early to mid June to determine whether damage is occurring. If so, a cultivator application may be needed as a rescue treatment.

Crop rotation. Crop rotation is an extremely effective way to prevent damage from northern and western corn rootworm larvae. If feasible, do not grow corn two years in succession in the same field. First-year corn following soybeans will generally not require a soil insecticide for rootworm control (see "Extended Diapause").

Although rootworm beetles can be found in "clean" or weed-free soybean fields, and may even lay a few eggs there, the number of eggs is not great enough to warrant the use of a soil insecticide on corn the following season. In a few instances, rootworm larval damage has occurred to corn planted after soybeans when the bean field had been heavily infested with volunteer corn or weeds during August of the preceding year. Adult northern and western corn rootworms were attracted to these fields to deposit eggs. As a result, root damage by larvae occurred the following season. Soybean fields that had 5,000 or more volunteer corn plants per acre in 1989 may warrant treatment for rootworm control in 1990 if they are planted to corn. Good weed control in soybeans will usually prevent rootworm damage in corn following soybeans.

Corn rootworm beetles deposit the vast majority of their eggs in cornfields. The larvae cannot survive on the roots of broadleaf crops (soybeans or alfalfa) or broadleaf weeds. Consequently, when a crop other than corn, soybeans for example, is planted in a field with soil containing millions of rootworm eggs, the rootworm larvae die from starvation.

Soil insecticides. *At planting.* Certain granular soil insecticides can be applied at planting time to prevent damage by corn rootworm larvae. The granules should be applied directly over the row in a 7-inch band ahead of the planter press wheel or firming wheel and lightly incorporated with spring tines or drag chains mounted behind the planter units. Some insecticides can also be applied in the seed furrow, but others are not labeled for in-furrow application because they either won't provide adequate root protection or they will cause seedling injury. Consult Tables 4 and 5 for recommended rates of application and proper placement.

Liquid insecticides labeled for rootworm control can be used by growers who do not have granular applicator attachments on their planters. These products are highly toxic, so **use extreme caution when handling liquid insecticide formulations.** Liquid insecticides may be either mixed with water and applied as a spray in a 7-inch band ahead of the press wheels, or they may be mixed with liquid fertilizer and used with a split-boot applicator at planting. However, *incompatibility or crop injury* may be a problem with combinations of a liquid insecticide and a liquid fertilizer. Conduct a test before planting to make certain that the two are physically compatible. Maintain agitation in the tank after mixing and during application to prevent separation. Consult Tables 4 and 5 for recommended rates of application and proper placement.

The rates suggested in Table 4 should not be exceeded for rootworm control. Research has shown that increasing the rates of soil insecticide application does not improve rootworm control. Increasing the rate of the product will not solve rootworm control problems and may even accelerate the onset of resistance in the rootworm population.

Proper calibration, placement, and incorporation of rootworm soil insecticides will improve the likelihood of good control. See the section "Calibration for Granular Soil Insecticides" in this circular.

Soil insecticides will give 50 to 70 percent control of corn rootworm larvae, which is usually adequate to prevent economic levels of larval damage in most fields. But in some heavily infested fields enough larvae may survive to cause economic levels of root damage, and beetle populations may be large enough to interfere with pollination.

Planting-time treatments applied in early April may provide only marginal control. Consider a cultivator application in late May or early June in such fields, rather than a treatment at planting time.

At cultivation. A cultivation-time application of a soil insecticide is an alternative to a planting-time application or may be used as a "rescue" treatment if the planting-time insecticide fails to control rootworm larvae. In either case, you should dig up several plants and examine the roots and surrounding soil for rootworm larvae and damage. If you find 3 or more larvae per plant and the field was not treated at planting, a cultivator application is warranted. If the field was treated at planting and rootworm larvae and damage are obvious in June, plan to apply a cultivator treatment. "Obvious" rootworm damage is characterized by brown root tips and roots that have been tunneled in or chewed back toward the base of the plant.

The insecticide should be applied on both sides of the row at the base of the plants just ahead of the cultivator shovels. Cover the insecticides with soil. The best time to apply a basal treatment of a soil insecticide at cultivation is usually in late May or early June if evidence of rootworm feeding damage is noted.

Soil moisture may affect both application and effectiveness of cultivation-time treatments. Fields that are too wet may never be cultivated. On the other hand, the insecticide may not perform satisfactorily if the soil is too dry.

Suggestions for alternating rootworm soil insecticides. Avoid using the same soil insecticide for several consecutive years or in fields where there have been performance problems. The continuous use of one insecticide may enable soil microorganisms to break it down more rapidly or may hasten the onset of insecticide resistance. **Illinois entomologists encourage growers to consider alternating rootworm soil insecticides, rather than**

using one product for several consecutive years. Consider the following suggestions for alternating rootworm soil insecticides:

1. If performance of a soil insecticide has been poor in a particular field in recent years, do not use the same insecticide in that field in 1990.
2. Avoid using carbamates in consecutive years.
3. Avoid using the same organophosphate or pyrethroid for several consecutive years.

Control of rootworm beetles to prevent egg-laying. Research conducted during the mid 1970s indicated that properly timed sprays to prevent rootworm beetles from laying eggs could eliminate the need for a soil insecticide the following year. However, the procedure is not foolproof. Factors beyond the control of the operator, such as beetle migration and weather, may minimize the treatment's effectiveness.

Growers who have experienced erratic rootworm control with soil insecticides the past few years and who are committed to a continuous corn program may look to beetle control as an alternative, or an addition, to soil insecticides at planting. Ideally, one properly timed spray should *replace* a soil insecticide. Unfortunately, some fields will require two sprays to combat extended beetle emergence and egg-laying. Two sprays or a spray plus a soil insecticide the following season may hasten the onset of rootworm resistance to insecticides.

It is important to recognize that control programs to prevent egg-laying and controlling beetles to prevent silk clipping do not overlap in time. Most eggs are laid from mid-August through early September, well after the time when treatments to prevent silk clipping would be necessary.

The prerequisites for a successful beetle suppression program are very complex. One must be able to identify both species (western and northern), to distinguish between the sexes, and to determine whether the females are gravid (eggs present). Frequent scouting trips and precise techniques are also requirements. A rootworm beetle suppression program should be employed only if the fields are under the supervision of properly trained pest management personnel. For more specific information about this rootworm management alternative, contact the Extension entomologists at the University of Illinois.

Summary: Planning your rootworm management program. A management plan for rootworms should be long range (not a year at a time) and include crop rotation, insecticide rotation, cultivator treatments, and scouting to determine the need for rootworm control.

1. Alternate corn with another crop when possible, particularly in fields where rootworm beetles averaged 0.75 or more per plant last summer, or if the soil insecticide did not give effective rootworm control in 1989.
2. If you intend to grow corn after corn and if rootworm beetles averaged 0.75 or more per plant in corn after corn or 0.5 beetle per plant in first-year corn last summer, apply a rootworm soil insecticide at planting time. Apply the rate suggested in Table 4 and consider our suggestions for alternating rootworm soil insecticides.
3. Consider a cultivation-time application of a rootworm soil insecticide if you intend to plant in early April or if your planting-time insecticide does not provide effective control.
4. Scout for rootworm beetles in July and August 1990 to determine the potential for rootworm larval damage in 1991.

Scouting to determine rootworm potential in 1991

The abundance of rootworm beetles in a cornfield in July and August is an indicator of potential rootworm problems the following year. You can determine the potential for rootworm damage in 1991 by counting western and northern corn rootworm beetles from mid-July through August, 1990, in this way:

1. Scout fields at least three times at 7- to 10-day intervals between mid-July and late August in fields to be replanted to corn.
2. Examine 5 plants selected at random in each of 10 areas of the field. Count all of the western and northern corn rootworm beetles on 50 plants each time. The counts take about 45 minutes in a 40-acre field.
3. As you approach a plant, move quietly to avoid disturbing the beetles. Count the beetles on the entire plant, including the ear tip, tassel, leaf surface, and behind the leaf axils.
4. Record the number of beetles you find per plant. If the average is more than 0.75 beetle per plant in corn after corn or 0.5 beetle per plant in first-year corn for any sampling date, plan to rotate away from corn or apply a rootworm soil insecticide to corn in 1991. If populations do not exceed an average of 0.5 beetle per plant for any sampling date, a soil insecticide will not

Table 1. Thresholds for Corn Rootworm Beetles (Average Number of Beetles per Plant) for Different Plant Populations and Cropping Sequences

Average number of plants per acre	Average number of beetles per plant	
	Continuous corn	First-year corn
14,000	1.4	1.0
16,000	1.3	0.9
18,000	1.1	0.8
20,000	1.0	0.7
22,000	0.9	0.6
24,000	0.8	0.6
26,000	0.8	0.5
28,000	0.7	0.5

be needed the following season.

Entomologists at Purdue University incorporate corn plant populations as well as cropping sequence into their decision-making procedures. Plant population affects thresholds simply as it relates to the number of beetles per acre. Table 1 shows the thresholds for different plant populations and cropping sequences. If the beetle count exceeds these thresholds, management of next year's larval population through crop rotation or insecticide application (corn following corn) is recommended.

European corn borers

European corn borer populations were very high in 1989 in some areas of Illinois. Very large first- and second-generation moth flights were observed in west central, north central, and northwestern counties of Illinois. Many producers in these areas treated for first-generation corn borers but neglected to scout and evaluate the damage potential of the second generation. Results of the 1989 fall survey indicated that many fields had large populations of corn borers and a high incidence of stalk breakage. Because of heavy feeding damage by second-generation borers, the potential for direct yield losses (dropped ears) was very high in 1989, especially for those producers who delayed harvest in seriously infested fields.

Overwintering populations (1989-90) of the European corn borer were much greater than they were in 1988-89. A mild winter with abundant snowfall will increase the survivorship of European corn borer larvae. The first flight of moths in 1990 is expected to be large; however, if spring conditions are characterized by stormy and cool weather, success of mating and egg-laying will be reduced.

The European corn borer (ECB) usually has two generations a year in Illinois. In some years there may also be a partial third generation in southern and central Illinois. There are four stages in each generation: egg, larva, pupa, and adult (moth). The ECB overwinters as a full-grown larva in corn stalks, cobs, and plant residue.

First generation

The ECB moths that lay eggs for the first generation begin to emerge in late May in southern Illinois and in mid-June to late June in the central and northern regions. The females lay most of their eggs in the evening and spend the daylight hours in fencerows and other protected areas (action sites).

First generation ECB larvae reduce yields by stalk-tunneling, which weakens the plant and destroys the tissue used to transport food within the plant.

Different corn hybrids have variable degrees of tolerance or resistance to leaf-feeding by first-generation borers. Consider this trait when selecting varieties.

Scouting procedure. Corn that is planted early (the fields with the tallest corn) should be monitored closely from mid-June to early July for signs of whorl-feeding by corn borer larvae. The fields with the tallest corn in mid-June are the most attractive to moths laying eggs for the first generation.

Plan to scout cornfields for damage at least once a week for a 2- to 4-week period following peak corn borer moth flight, generally from early June to early July.

To determine the need to treat, examine 100 plants (20 consecutive plants at 5 different locations in a field) for shot-hole feeding in the whorl leaves. Unroll the whorl leaves of 10 infested plants (those with shot-hole feeding) and count the *live* corn borers per infested plant. Calculate the percentage of plants infested and the average number of live borers per infested plant. Also note the location of the corn borer larvae. Those that are still in the whorl leaves can be controlled, while those that have bored into the stalk are protected from the insecticide. If all larvae have left the whorl leaves and bored into the stalk, it is too late to apply a treatment.

Treatment guidelines. To decide whether it will be profitable to treat a field infested with first-generation corn borers, the following information is needed:

1. Average percentage of plants with whorl feeding.
2. Average number of larvae per infested plant.
3. Expected yield per acre.
4. Value of grain per bushel.
5. Cost per acre for insecticide treatment.

Enter these data into the worksheet below to calculate the gain or loss for applying an insecticide to control corn borers.

Second generation

European corn borer moths laying eggs for the second generation are attracted to fields of corn that have recently tasseled or are in the pollen shedding or green silk stage. Late-planted fields of full-season hybrids are usually more attractive and are more likely to sustain economic damage.

Yield losses caused by second-generation ECB are primarily the result of physiological injury, although stalk breakage and ear droppage may become significant if harvest is delayed. Stalk tunneling by corn borers also increases the likelihood of stalk rot.

Scouting procedure. To assess the need for controlling second-generation ECB, start checking for egg masses when moth flight is under way, usually around mid-July in southern Illinois and late July to mid-August in central and northern Illinois. Concentrate initial scouting efforts in late-planted fields where the probability of an economic ECB infestation is greatest.

Examine a minimum of 25 plants, selected at random throughout the field, and count the number of ECB egg masses that are found on each plant. European corn

Management Worksheet
for First-Generation
Corn Borer

______ % of 100 Plants Infested × ______ Average No. Borers/Infested Plant = ______ Borers/Plant
(determined by checking whorls from 10 plants)

______ Borers/Plant × 5% Yield Loss/Borer = ______ % Yield Loss

______ % Yield Loss × ______ Expected Yield (Bu/A) = ______ Bu/A Loss

______ Bu/A Loss × $______ Price/Bu = $______ Loss/A

$______ Loss/A × ______ % Control = $______ Preventable Loss/A
(80% for granules)
(50% for sprays)

$______ Preventable Loss/A − $______ Cost of Control/A =
$______ Gain (+) or Loss (−) per acre if treatment is applied

Management Worksheet
for Second-Generation
Corn Borer

______ Number of Egg Masses/Plant × 2 Borers/Egg Mass* = ______ Borers/Plant
(cumulative counts, taken 7 days apart)

______ Borers/Plant × __4__ % Loss/Borer** = ______ % Yield Loss

______ % Yield Loss × ______ Expected Yield = ______ Bu/A Loss

______ Bu/A Loss × $______ Price/Bu = $______ Loss/A

$______ Loss/Acre × __75__ % Control = $______ Preventable Loss/A

$______ Preventable Loss/A − $______ Cost of Control/A =
$______ Gain (+) or Loss (−) per acre if treatment is applied

* Assumes survival rate of 2 borers/egg mass.
** Use 3% per borer per plant if infestation occurs after silks are brown. The potential economic benefits of treatment decline rapidly if infestations occur after corn reaches the blister stage.

borer moths usually lay their eggs on the underside of the two or three leaves above or below the developing ear. However, you should check all leaves on the plant for egg masses. One technique is to remove the leaves one by one, starting at the bottom of the plant, and carefully scan them for egg masses. The eggs, which are deposited in masses of 15 to 30, overlap like the scales of a fish.

Egg masses are flat and about ¼ inch in diameter. Newly deposited eggs are white, then turn pale yellow, and become darker just before hatching. Eggs that are about to hatch have distinct black centers. These are the black heads of the larvae that are visible through the translucent eggshell. The eggs hatch in 3 to 7 days, depending on the temperature.

The female moth rests in grassy areas during the day. Noncrop areas that border cornfields may harbor large numbers of corn borer moths. Check these areas for moths as you enter the field to determine the potential for corn borer infestation.

Calm nights favor egg deposition by the moths. The absence of hard, beating rains during moth emergence also increases the potential for infestations.

Treatment guidelines. To determine whether it will be profitable to treat a field to control second-generation corn borers, the following information is needed:

1. Average number of ECB egg masses per plant.
2. Crop maturity.
3. Expected yield per acre.
4. Value of corn per bushel.
5. Cost per acre for insecticide treatment.

For best results, treatment should be applied soon after egg hatch to kill the young larvae before they bore into the plant. The larvae begin tunneling into the stalks about 10 days after hatching. Occasionally, two treatments may be necessary for satisfactory control if egg laying extends over a 3- to 4-week period.

Grape colaspis

The grape colaspis overwinters as a small larva in the soil. In early spring, the larvae move toward the soil surface and feed on corn and soybean roots. They complete their larval development in mid-June to early July and then enter the pupal, or resting, stage. Adults emerge from the soil in late July and can be found during August in clover, alfalfa, soybeans, corn, and patches of smartweed. The eggs hatch in early fall.

The grape colaspis larva is about ⅛ to ⅙ inch long when fully grown and is shaped like a comma. It has a rather fat, white body and a yellow-brown head. The adult is a yellowish brown, elliptical beetle that resembles a northern corn rootworm. Unlike the northern corn rootworm, the wing covers of the grape colaspis are marked with longitudinal rows of ridges with evenly spaced punctures.

Grape colaspis larvae feed on the roots and root hairs of both corn and soybeans, preventing the plants from getting enough moisture and nutrients. They also scarify the roots and eat out narrow strips on the root. The first symptom of colaspis damage to corn is purpling and wilting of the leaves. Damaged soybean plants are wilted. If the infestation is severe enough, the leaves turn brown and die, and plant populations are reduced. Rapidly growing, healthy corn and soybean plants often do not show symptoms of feeding damage due to grape colaspis.

Because colaspis beetles lay their eggs in red clover and soybeans, the potential for damage is greatest in fields of soybeans and corn planted after soybeans or red clover. However, if growing conditions are ideal during the spring, grape colaspis probably will not be a prevalent problem.

The use of a soil insecticide to prevent damage from grape colaspis is not warranted. In fact, none of the currently available soil insecticides is labeled for control of grape colaspis in either corn or soybeans.

In addition, there are no effective rescue treatments for grape colaspis after the damage appears. If plants show symptoms of injury, dig around the root system of several plants. If grape colaspis larvae are causing the problem and replanting is warranted, consider applying an insecticide that is labeled for control of white grubs.

Stalk borers

Fields that are to be planted to corn in 1990 and were infested with living quackgrass, giant foxtail, ragweed, or wirestem muhly during August or September 1989 should be monitored carefully for stalk borer damage in the spring. Stalk borer moths deposit their eggs on leaves and stems of grasses during the later months of the summer. Eggs overwinter and hatch in late April to early June. Larvae can be identified easily by the prominent white and purple longitudinal stripes running the length of their bodies; the stripes are interrupted about midway by a dark purple band. After egg hatch, young stalk borers begin an active search for a host plant stem into which they will burrow. As the larvae mature and increase in size, they leave their weed host to seek a larger plant.

Young stalk borer larvae infest small corn plants either by burrowing directly into the stem or by crawling down into the whorl and then burrowing in the stem. Upper leaves are often cut off from within the plant, and they wilt and die quickly. Outer leaves may remain green and appear normal. Larvae may also feed directly on growing point tissue in young plants, causing stunting or death of plants. The symptom for this type of injury is referred to as "dead heart." Plants that are infested but are not killed often remain barren.

Corn plants adjacent to fencerows, grass conservation lanes, or grassy terraces where stalk borers laid eggs the previous summer are most likely to be infested by larvae in the spring. If grass control the previous season was poor throughout the field, an infestation of stalk borers can be widespread. In addition, corn planted no-till into grassy vegetation is a good candidate for stalk borer injury.

Rescue treatments are not effective after the stalk borers have tunneled into the corn plants. Ideally, postemergence sprays should be applied when larvae are moving from their initial weed hosts to young corn plants, but timing this event is very difficult. Often by the time stalk borer damage is noticed, it is too late to do anything except consider replanting the infested area of the field. If replanting is warranted and damaged plants won't be disked under, an insecticide should be applied as soon as plants begin to spike. This treatment should prevent larvae from infesting the most recently planted corn. One of the best methods of reducing the potential for stalk borer damage is a good weed control program that eliminates suitable egg-laying sites (grassy weeds) within a field.

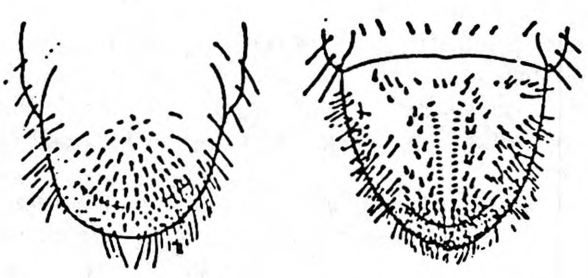
White grubs

Several species of economically important white grubs have three-year life cycles. Peak years of damage usually occur during the year following large flights of May beetles, the adult stage of white grubs. The beetles prefer to lay their eggs in ground covered with vegetation, such as weedy soybean fields and sod.

The C-shaped white grub larvae chew on the roots and root hairs of corn seedlings. During peak years of damage, the grubs feed all season long. Damage to a cornfield is most apparent in the spring. Symptoms of white grub injury visible aboveground are irregular emergence, reduced stands, and stunted or wilted plants. The damage is usually spotty throughout the field.

There are no effective rescue treatments for white grubs after the damage appears. However, if plants show symptoms of injury, dig around the root system of several corn plants. If white grubs are causing the problem and replanting is warranted, use a labeled soil insecticide.

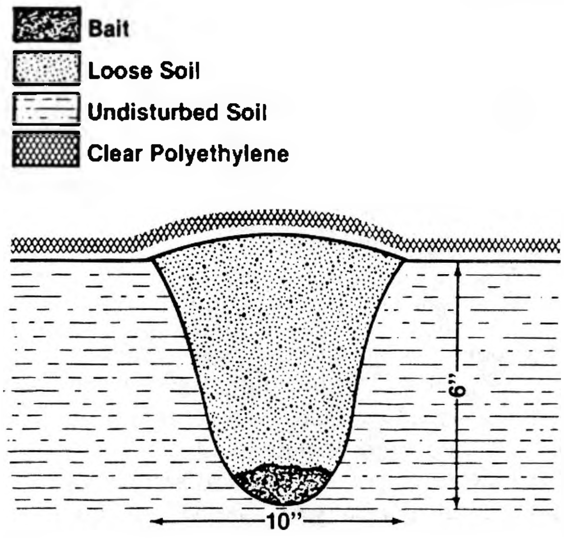
One way to detect the presence of white grubs is to look for them during spring tillage operations. However, if you turn up grubs during spring tillage, be sure to identify them correctly by examining the pattern of hairs on the underside of the last abdominal segment (see diagram). True white grubs (right), the species that may damage corn, have two parallel rows of hairs on the underside of the abdomen. Annual white grubs (left) have a more random pattern of hairs, and they rarely cause economic damage to corn. The presence of true white grubs during spring tillage operations might warrant application of a soil insecticide.



Last Abdominal Segment of Annual and True White Grubs

Wireworms

During the past five years wireworm damage to corn has occurred with increasing frequency. Even so the



Cross Section of a Wireworm Solar Bait Station

proportion of fields of corn affected by wireworms in Illinois is small (less than 1 percent) and does not justify the widespread use of a soil insecticide on first-year corn after soybeans. A lindane or diazinon + lindane planter-box seed treatment may help deter the wireworms from attacking the seed but will not protect the seedling.

Wireworms may attack the seed or drill into the base of the stem below ground level, damaging or killing the growing point. Damage will show up as wilted, dead, or weakened plants and spotty stands. Wireworm larvae are reddish- or yellowish-brown and wirelike; several species are known to attack corn. They live for two to five years in a field in the larval stage, feeding on the roots of grasses and crops. Their presence is often related to the crops or weeds that were in the field two to four years before damage to the corn is apparent. Most reports of damage to corn have been in fields where corn follows soybeans or where there has been a corn-soybean-small grain rotation. The adult (a click beetle) prefers to deposit its eggs in small-grain stubble or in grassy fields.

Wireworms are usually most damaging in bottomlands or in poorly drained areas on upland soils. Low spots in the field often have the heaviest populations.

Attempts to control wireworms with an insecticide rescue treatment after the damage appears are not very successful. Therefore, if an infestation is known to be present, an insecticide should be applied at planting.

Checking for wireworms

A technique using baits has been developed for evaluating wireworm potential before planting. The bait stations should be established 2 to 3 weeks before the anticipated planting date. Fields where small grain or grasses have been grown the preceding 2 or 3 years are the best candidates for bait stations.

Since wireworm infestations are usually not uniform within a field, it will be necessary to place the bait stations randomly throughout the field. One bait station per acre is desirable. If you cannot place one bait station per acre, be sure that your baiting program adequately represents all different areas of the field.

Follow this procedure for baiting:

1. Use a mixture of 1 cup of untreated wheat and 1 cup of untreated shelled corn at each station.
2. Bury the bait about 4 inches deep. It is also desirable to cover the ground over each bait station with an 18-inch square of clear plastic (see diagram). The plastic collects solar heat and speeds germination of the corn and wheat, which attracts overwintering wireworms.
3. Mark each station with a flag or stake.
4. Dig up the bait stations in 10 to 14 days and count the number of wireworms.

Need for treatment

If you find an average of one or more wireworms per bait station, use a labeled soil insecticide. In some instances, several wireworms may be found in one bait station and none in others. Wireworm infestations tend to concentrate in some locations. It may be possible to limit treatment to areas where the concentration of wireworms is heaviest.

Soybean Insects

Bean leaf beetles

Bean leaf beetle populations in soybeans were much lower in 1989 than in 1988. Producers were told well in advance to scout their seedling soybeans for bean leaf beetles because of the large overwintering population (1988-1989); however, very few soybean fields were seriously damaged. If survival of overwintering beetles during the mild winter of 1988-1989 was very good, as we believe it was, why then were so few fields affected by bean leaf beetles in 1989?

After the adults left their overwintering sites (residue in fencerows, wooded areas, and other protected sites), they flew into alfalfa fields and remained there until soybeans emerged. We believe that many bean leaf beetles were killed in alfalfa fields that were treated for alfalfa weevils. Alfalfa weevil populations were extremely high in 1989 and a large percentage of the alfalfa acreage was treated. Bean leaf beetle populations remained low throughout the early portion of the growing season.

Although pod feeding by the second generation was not unusually heavy in all areas of the state, populations of bean leaf beetles late in the season seemed to be reasonably large. As a consequence, producers should be alerted to the potential for seedling injury to soybean fields next spring, especially if the winter is mild.

As temperatures warm above 55°F, the bean leaf beetles fly to alfalfa, clover, or seeds to feed. If soybeans are planted early in 1990, however, the beetles will abandon the forage fields or move directly from hibernation sites to colonize and feed on the leaves of the early emerging bean seedlings. Soybeans can withstand considerable leaf feeding during the vegetative (prebloom) stage, but treatment may be necessary if defoliation reaches 30 percent and at least one cotyledon per foot of row is destroyed.

In addition to feeding on the leaves, the adults lay eggs in the soil near the soybean plant. Egg hatch commences in late May, and the larvae feed on the roots and nodules of the soybeans during June. Adults of the first generation emerge in July. These beetles feed on the soybean foliage, lay eggs, and the new larvae emerge as second-generation adults during August and September. These adults do not lay eggs, although they stay in soybean fields as long as there are green leaves or tender pods to chew on. As soybeans mature, and temperatures fall, the beetles fly to winter hibernation sites.

The availability of early emerging soybeans is essential for the survival of bean leaf beetles coming out of winter hibernation sites. A large acreage of early planted soybeans generally results in the survival of large numbers of bean leaf beetles early in the season and even larger adult populations in August. Conversely, a severe winter and later-planted soybeans will reduce the rate of survival of bean leaf beetles in the spring and also the size of first- and second-generation populations.

Insecticide treatments are recommended during the critical pod-set and pod-fill stages when defoliation exceeds 20 percent. The greatest concern, however, is caused by the beetles' feeding on pods, which leaves scars on many pods. These scars predispose the pods to fungal infections. Beans within the damaged pod may be discolored, deformed, or moldy. A treatment is recommended when 5 to 10 percent of the pods are damaged.

Grasshoppers

Grasshopper populations were highest in west central and northwestern Illinois during 1989, both areas that were hit hard by the drought in 1988 and experienced hot, dry weather again in 1989. Outbreaks of grasshoppers frequently occur in years following a drought because naturally occurring fungal and bacterial diseases do not thrive under hot, dry conditions. These diseases usually suppress grasshopper populations only during periods of warm, humid weather. We do not anticipate a widespread problem with grasshoppers during the 1990 growing season, but growers in areas afflicted by drought in 1989 should maintain a close vigil in the spring.

Several species of grasshoppers have the potential to damage soybeans by feeding on leaves or pods, but redlegged and differential grasshoppers are the species most commonly found. Eggs are glued together and deposited in the soil in batches during late summer and fall until the first frost. The eggs overwinter and hatch the following spring. Tillage operations to cropland have very little effect on species such as the differential grasshopper because their egg masses are deposited in uncultivated areas like roadsides, fencerows, and field edges. The redlegged grasshopper tends to lay eggs in field margins, roadsides, pastures, meadows, and forage crops.

Grasshopper nymphs can be found feeding in noncrop areas for roughly 40 to 60 days during the spring. This is an important management consideration because grasshopper populations are most easily managed when the grasshoppers are in the nymphal stage. Nymphs are less mobile than adult grasshoppers because they lack functional wings, and their thin cuticle (skin) makes them easier to kill with insecticides. As vegetation in ditch banks and fencerows is mowed or dries out, nymphs begin to move into adjacent rows of soybeans. If nymphal populations average 15 to 20 per square yard in noncrop areas bordering a soybean field, an insecticide labeled for use in these sites should be considered.

After grasshoppers move into soybean fields, the economic thresholds are based upon percentage defoliation or degree of pod injury. An insecticide application may be warranted when defoliation reaches 30 percent prior to the bloom stage or 20 percent between bloom and pod fill. Grasshoppers can also cause direct yield losses by feeding on the pods. Unlike bean leaf beetles that feed primarily on the outer surface of the pod, grasshoppers chew directly through the pod and feed on developing seeds. If 5 to 10 percent of the pods have been fed upon and grasshoppers are actively feeding, an insecticide treatment may be justified.

Stink bugs

Brown and green stink bugs have the potential each year in Illinois to damage developing soybean seeds. These two species of insects have piercing and sucking mouthparts with which they penetrate pods and puncture seeds. Immature stink bugs (nymphs), as well as adults, feed on plant juices, but only the older nymphs and the adults feed on seeds within the pods.

Adult stink bugs are large (⅝ inch long), "shield-shaped" insects. The nymphs usually shed their skins four times (requires approximately 45 days) before reaching the adult stage. Nymphs can be recognized easily because of their bold arrangement of colors consisting of black, green, yellow, and red striped zones.

Stink bugs overwinter in wooded areas or other protected sites away from fields. During the early summer months after they emerge, stink bug adults feed on berries in trees. Soybean fields are not invaded until pods are beginning to set in August. Only one generation of stink bugs occurs each year in soybean fields.

Yield losses may occur due to a combination of factors: direct loss of plant juices, injection of digestive enzymes, and the entrance of diseases through the wound site. Young seeds that are injured usually abort, and more mature seeds may be discolored or malformed. If a bug punctures the embryo, the seed will not germinate. Stink bugs are also capable of transmitting yeast spot disease. In addition to direct yield losses, seed quality may be reduced due to a reduction in oil content which causes greater deterioration during storage.

Soybean fields should be monitored for stink bugs even after the leaves begin to turn yellow and drop from plants. Stink bugs are late-season pests that remain in the fields well into September. Because stink bugs damage the seeds directly, 1 adult or large nymph per foot of row found during the pod fill stage is the recommended economic threshold.

Twospotted spider mites

Many soybean producers were wary of spider mites during 1989 because of their experience with the outbreak in 1988. However, because rainfall was generally more abundant and relative humidities were much higher in 1989 than in 1988, populations of twospotted spider mites remained at noneconomic levels on soybeans throughout most of Illinois. Unfortunately, some areas repeatedly missed rain showers, and populations of spider mites began to build. Some injured soybeans were treated for spider mites in 1989, but some of these fields were later diagnosed as fields in which herbicides had carried over.

Mites are not insects but are closely related arthropods. Mites hatch from very small eggs, which with the aid of a magnifying glass can be seen on the undersurface of soybean leaves. Larvae with six legs emerge from the eggs and progress through two nymphal stages, each with eight legs. Following the last nymphal molt, the eight-legged adults emerge, representing the reproductive stage of the life cycle. The time necessary to complete a generation ranges from 1 to 3 weeks and depends on environmental conditions, primarily temperature.

Mites have piercing and sucking mouthparts with which they puncture plant cells and remove plant juices. Once plant cells have been damaged, they do not recover. Foliage that has yellow and brown stippling and webbing on the undersurface of the leaves is characteristic of mite damage. Severe infestations may cause complete defoliation of soybean plants. Mites can move very easily throughout fields by ballooning, that is, by spinning webs and moving to a position on a leaf from which they can be blown aloft. Mites can also go from row to row by bridging (moving across leaves in contact) when canopy closure is near completion. Border rows are frequently the first areas of a field that are infested as mites move from nearby grasses and weeds in ditch banks.

If temperatures are moderate and precipitation is near normal during the 1990 growing season, spider mites should not be a problem. The economic threshold for twospotted spider mites is not clearly defined. When mites and symptoms of their feeding damage are obvious, a treatment may be justified. Confining the insecticide application to border rows and other areas of confirmed infestation continues to be the recommended management strategy when mites and damage are found.

Alfalfa Insects

Alfalfa weevils

Alfalfa weevils caused serious damage to alfalfa in 1989. Overwintering populations during 1988-1989 were large, and warm spells during the winter allowed alfalfa weevil adults to lay even more eggs. The early onset of spring brought on the early appearance of alfalfa weevil larvae and subsequent severe defoliation in southern Illinois. Some fields had to be sprayed more than once to prevent significant economic yield loss.

In northern Illinois, alfalfa weevils usually do not lay eggs in the fall. However, it has been speculated that some fall and winter egg-laying occurred, so large populations of alfalfa weevils severely damaged the first spring crop. In addition, many weevil larvae survived the first cutting and continued to damage the regrowth of the second crop. It was reported that some fields were so badly damaged that plants were killed and the stands were reduced.

Alfalfa weevil larvae go through four larval instars, but most of the damage is caused by the last instar. Early instar larvae are yellowish in color and are usually found in the folded terminal leaves. Older larvae are bright green with a black head and a white stripe along the center of the back. After they have completed their development, fully grown larvae spin netlike cocoons on the leaves or in the debris on the ground. Transformation from larva to adult takes place within the cocoon. Adult alfalfa weevils are light brown with a darker brown band along the center of the back. They have a characteristic snout which bears chewing mouthparts.

Numbers of alfalfa weevils are regulated to a large extent by winter weather. During a cold, open winter the mortality rate is high in overwintering weevil populations; during mild winters the mortality rate is low.

A parasitic wasp and a fungal disease may regulate weevil numbers in the spring. Although the wasp and the fungus will be present in alfalfa fields in 1990, we cannot yet predict their effect on weevil numbers. In general, wet weather promotes the spread of the fungal disease throughout the weevil population.

Alfalfa growers in southern and central Illinois should inspect their fields closely in April, May, and June. Early larval damage appears as pinholes in the growing terminals. As the larvae grow, they skeletonize the leaves, and damaged fields appear tattered. Growers in northern Illinois should look carefully for larval damage in May and June. Follow the suggestions in Circular 1136, *Alfalfa Weevil Pest Management Program,* to determine the need and proper timing of a treatment. If this circular is unavailable, a rule of thumb is to treat when 25 to 40 percent of the tips are being skeletonized, depending on the height of the crop.

All growers should examine the stubble after the first cutting of alfalfa has been removed. Surviving larvae and newly emerged adults will feed on the crown and stem buds and either delay or prevent regrowth. Control may be warranted after a cutting when larvae and adults are feeding on more than 50 percent of the crowns and regrowth is prevented for 3 to 6 days.

Potato leafhoppers

Potato leafhoppers also caused significant damage to alfalfa fields in Illinois in 1989. Leafhoppers do not survive the winter in the Midwest; they migrate from the Gulf states into Illinois during May and June. The numerous storm fronts that passed through Illinois in 1989 brought large numbers of leafhoppers into the state. After the leafhoppers arrived, environmental conditions were very good for their survival and development, so large populations occurred in many fields.

The adult potato leafhopper is a tiny, yellowish-green to lime green, wedge-shaped insect about ⅛ inch long. The nymphs resemble the adults in overall body shape, but they are wingless and usually have a more pronounced yellowish coloring. Both life stages are very active insects; the adults jump or fly when disturbed, and the nymphs characteristically move sideways.

Female potato leafhoppers insert their eggs into the stems and large leaf veins of alfalfa plants. The eggs hatch in 6 to 9 days, depending on the temperature. The leafhoppers go through five nymphal instars in about 2 weeks before becoming adults. Because the life cycle is short and females lay eggs for 6 to 8 weeks, generations overlap throughout the season.

Potato leafhoppers may cause moderate to severe damage to the second and third cuttings of alfalfa in all areas of Illinois. Damage first appears as a yellow, wedge-shaped area at the tip of the leaf. Many people confuse the damage with diseases or nutrient deficiency. Injury caused by potato leafhoppers can reduce both the yield and nutritional quality of the hay, and the effects of damage to one cutting can carry over to the next cutting or even into the next growing season. As a consequence, early detection of leafhoppers with a sweep net is extremely important.

Damage may begin on the new growth as soon as the first hay crop is removed. Stunting and yellowing are signs of leafhopper injury. A swarm of leafhoppers at the time of the first cutting also indicates that there may be a problem in the new growth. The economic threshold for leafhoppers varies with the height of the alfalfa (see Table 2). A treatment is justified when the number of leafhoppers exceeds the economic threshold.

Table 2. Economic Thresholds for Potato Leafhoppers on Alfalfa

Alfalfa height (inches)	Average number of leafhoppers per sweep of sweep net
0-3	0.2
3-6	0.5
6-12	1.0
12 or taller	1.5

Wheat Insects

Aphids

Several species of aphids can be found in wheat fields: English grain aphid, oat bird-cherry aphid, yellow sugarcane aphid, and greenbug. Of this group, only the greenbug is a potential threat to wheat in Illinois. Typically many beneficial insects naturally reduce aphid populations. Some of the common predators and parasites are ladybird beetle adults and larvae, syrphid fly larvae, lacewing adults and larvae, and tiny parasitic wasps.

Correct identification of an aphid species is important in assessing its potential impact on wheat yields. The greenbug, currently the only potentially threatening species, is bright green with a dark green stripe down the middle of the back. The tips of the cornicles ("tail pipes") that extend from the top rear portion of the abdomen are black or darkened. The oat bird-cherry aphid is olive green with a reddish-orange band on the rear of the abdomen. The tips of the cornicles are black. The English grain aphid is bright green and has long, narrow cornicles that are entirely black. The yellow sugarcane aphid is bright lemon yellow and has very short cornicles and conspicuous hairs.

The Russian wheat aphid, a species not yet found in Illinios, is pale green, has extremely short cornicles, and has a "double-tailed" appearance when viewed from the side. This insect has caused severe injury to wheat in the Great Plains states, so entomologists throughout the country are monitoring its progress to the east.

Armyworms

Armyworms damaged both corn and wheat during the spring of 1989. The outbreak was probably a result of the drought conditions of 1988 reducing the populations of natural enemies that usually hold armyworms in check. However, toward the end of June 1989, naturally occurring diseases killed many armyworms, so damaging levels of the later generation of armyworms did not materialize.

Armyworms do not overwinter in Illinois. Like the black cutworm, armyworm moths fly or are blown into Illinois on storm fronts early in the spring. The moths seek rank, grassy vegetation on which to deposit their eggs, and wheat fields are favored egg-laying sites.

The armyworm has six larval instars and requires about 3 to 4 weeks to complete larval development. The last (sixth) instar feeds for about 7 days and consumes more than 80 percent of all foliage eaten during the entire larval period. Smaller larvae often go unnoticed, so the damage seems to appear very suddenly. Large populations of fully grown armyworms can strip a field in a couple of days. If they completely defoliate a field, they may feed on awns and tender kernels and cut through the stem just below the head.

Economic damage to wheat occurs when armyworms consume the flag leaves, clip off heads, and chew on kernels. Control is probably warranted when there are six or more nonparasitized armyworms (¾ to 1¼ inch long) per linear foot of row and before extensive head cutting occurs. Also consider the ratio of fully grown to partially grown larvae and the presence of larvae infected with disease when you make a control decision. When most or all of the worms are full grown, the damage level has probably peaked and pupation will begin soon. Also, if a significant percentage of the larvae are diseased or parasitized, chemical control may not be necessary.

Cereal leaf beetles

The cereal leaf beetle has caused injury to wheat in southern and central Illinois for the past 2 years. The mild winters and lush fall growth have provided excellent overwintering conditions for the beetles.

The cereal leaf beetle adult is a hard-shelled beetle about $\frac{3}{16}$ inch long. Its wing covers and head are metallic bluish-black, while its legs and the front segment of its thorax (just behind the head) are reddish-orange. The larva is slightly longer than the adult and resembles a slug. Its skin is yellow to yellowish-brown, but the larva carries a moist glob of fecal material on its back that gives it a black appearance.

The adults overwinter in clusters in sheltered areas such as ground debris. In the spring, the beetles fly to fields of winter wheat and other small grains. When spring oats emerge, the beetles will quickly infest the young plants. They feed for about 2 weeks before they lay eggs. Eggs usually hatch in 5 days, and the larvae usually take 10 days to become full grown. After the larvae finish feeding, they descend to the ground and pupate in the soil. After 2 to 3 weeks, new beetles emerge. These beetles often fly to the edges of cornfields and feed on the leaves. After feeding for about 2 weeks, the beetles go into summer hibernation.

The larvae eat only the outer surface of the leaves, so damaged plants are silvery in appearance. Severely damaged fields appear frosted. Yield losses occur when the larvae concentrate their feeding on the flag leaves. Control may be warranted when there is an average of one or more larvae per stem. Adults eat longitudinal slits between the veins and completely through the leaves of both wheat and corn. Corn plants usually recover from this injury.

Insecticides for Insect Management

The insecticides suggested for use in this circular are based on registrations granted by the U.S. Environmental Protection Agency (EPA). Not all insecticides registered for control of crop insect pests are included. Effective insecticides that do not present an undue hazard to the user or the environment are suggested whenever possible.

At the time this publication was in preparation, only currently registered insecticides were included. New registrations and changes in registration, labels, and recommendations will be announced through appropriate media sources and county Extension advisers.

The insecticide recommendations in this circular are provided for educational purposes only. Trade names of insecticides have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise the usual caution in making purchases or evaluating product information. **Always consult the insecticide label for specific instructions, application rates, and precautions before applying an insecticide.**

Insecticide Nomenclature

The chemical names used in this circular may be unfamiliar to you. These names are the common, coined chemical names and as such are not capitalized (e.g., terbufos). Trade names are capitalized (e.g., Counter). In the tables of suggestions for control, only the trade name is listed. In the table of limitations (Table 12), the trade names are listed first, with the common names in parentheses following the trade names.

Federal and State Laws

The U.S. EPA classifies pesticides for ***general*** or ***restricted*** use (Table 3).

Commercial applicators who apply restricted-use pesticides must be certified. Commercial applicators include persons applying a pesticide for hire and governmental personnel, chemical company representatives, and others involved in demonstrational, regulatory, and public health pest control. Certification as a commercial applicator requires passing written examinations administered either by the Illinois Department of Agriculture or the Department of Public Health.

Private applicators (farmers) who use restricted-use pesticides for the purpose of producing any agricultural

Table 3. Insecticide Classifications

Trade name	Common name	Classification
*Aastar	flucythrinate + phorate	restricted
*Ambush	permethrin	restricted
*Asana	esfenvalerate	restricted
Broot	trimethacarb	general
*Counter	terbufos	restricted
Cygon	dimethoate	general
Cythion	malathion	general
Diazinon	diazinon	general
Dipel	*Bacillus thuringiensis*	general
*Dyfonate	fonofos	restricted
Dylox	trichlorfon	general
*Force	tefluthrin	restricted
*Furadan	carbofuran	restricted
Imidan	phosmet	general
*Lannate	methomyl	restricted[a]
Larvin	thiodicarb	general
Lorsban	chlorpyrifos	general
Malathion	malathion	general
*Mocap	ethoprop	restricted
Orthene	acephate	general
*Penncap-M	methyl parathion (microencapsulated)	restricted
*Pounce	permethrin	restricted
*Pydrin	fenvalerate	restricted
Sevin	carbaryl	general
*Supracide	methidathion	restricted
*Thimet	phorate	restricted

[a] All formulations except water-soluble packages, 25% wettable powder, and granulars are restricted.

Asterisks (*) are used throughout this circular to indicate insecticides classified for "restricted" use.

commodity on property owned, rented, or otherwise controlled by them or their employer, or as exchange labor (no compensation) on the property of another must be certified by passing a written examination.

Certification via written examination and the issuing of permits or licenses are handled by the Illinois Department of Agriculture. Training programs for farmers (private applicators) and commercial pesticide applicators are conducted by the Cooperative Extension Service to prepare persons for certification. For additional information about training programs, consult your county Extension adviser in agriculture.

Special local need registrations

Section 24(c) of the amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972 allows states the right to register pesticides for use within the state to meet special local needs (SLN). The authority for state registration of pesticides is the Illinois Department of Agriculture. A special label, which lists the new 24(c) uses, is printed by the formulator. A copy of this label must be in the possession of the operator during application of the pesticides.

Emergency registrations

Section 18 of the amendments to FIFRA allows the U.S. EPA to exempt any federal or state agency from provisions of FIFRA if the EPA determines that emergency conditions exist. This section allows for the use of a pesticide not currently labeled for a particular crop if emergency conditions, such as an insect outbreak, exist. "The Administrator (of the U.S. EPA), in determining whether or not such emergency conditions exist, shall consult with the Secretary of Agriculture and the Governor of any State concerned if they request such determination."

Groundwater protection

The U.S. EPA has started requiring pesticide manufacturers to include groundwater statements on labels if the product has been detected in samples of groundwater associated with monitoring programs.

Most groundwater statements now on labels have identical wording: "*Pesticide X* is a chemical which can travel (seep or leach) through soil and can contaminate groundwater which may be used as drinking water. *Pesticide X* has been found in groundwater as a result of agricultural use. Users are advised not to apply *Pesticide X* where the water table (groundwater) is close to the surface and where the soils are very permeable, i.e., well-drained soils such as loamy sands. Your local agricultural agencies can provide further information on the type of soil in your area and the location of groundwater."

Groundwater statements that are present on labels help the applicator to choose appropriate treatments where soils are sandy or where extra precautions are needed to reduce the risk of groundwater contamination. Pesticide applicators should use alternative products in areas with sandy soils and shallow groundwater.

Currently, the only agricultural **insecticide** product that includes a groundwater statement on the label is Furadan.

The leaching potential of pesticides is affected by many properties, including how tightly they are adsorbed by soil particles, solubility, and persistence. Adsorptivity, solubility, and persistence properties of pesticides are usually not included on pesticide labels.

Endangered species act

In 1973, Congress passed the Endangered Species Act to protect America's endangered plants and wildlife. That act requires the U.S. EPA to ensure that these species are adequately protected from pesticides.

At the present time, it is working to develop an Endangered Species Protection Program in fulfillment of this mandate. The goal of this program will be to remove the potential hazard to endangered species posed by pesticide use. A concurrent goal of this agency is to avoid placing any unnecessary limitations on the use of many important pesticides.

Role of the EPA. The federal government has a clearly defined legal responsibility to protect native plants and animals from hazards posed by pesticides. The EPA's role, as defined by Congress, is to register pesticides and set conditions for their use. FIFRA, one of the EPA's principal statutes, charges the EPA with protecting the environment and health from "any unreasonable adverse effects" of pesticides. In addition, the Endangered Species Act requires all federal agencies to ensure that their actions do not jeopardize endangered species.

Program Implementation. The Endangered Species Protection Program will utilize a species-based approach to biological consultation. Species will be ranked based on their status, recovery potential, potential for exposure, the apparent risk to their continued existence from pesticides, and other factors which EPA deems a threat to their existence. EPA will first focus on the listed species with the greatest need for protection. They will gather information on the habitats and locations of these species and determine the pesticides to which the species may be exposed.

Once the species and associated pesticides have been selected for consideration, the species will be screened to determine whether the use of the pesticides may affect them. As part of this "may affect" determination, EPA will determine the lowest application rate of the pesticide that could affect a species or its habitat. EPA will then request a consultation with the Fish and Wildlife Service (FWS) for the specific pesticide rates, methods, and uses that may affect listed species. The FWS will respond with a biological opinion indicating whether or not the species is in jeopardy from the pesticide use. If jeopardy is found, FWS and/or EPA will proceed to develop habitat maps that will become part of the pesticide labeling/bulletin instructions. Not all pesticides that EPA determines "may affect" a listed species will necessarily be found by the FWS to cause jeopardy to a species. Among other criteria, the jeopardy declaration can be based on an assessment of whether a species will actually be exposed to the pesticide in question.

The product label will not list the counties in which limitations on pesticide use apply. Instead, the labels of affected products will require users in all counties to comply with the use limitations contained in the bulletin for the county in which they intend to use the pesticide. In counties where no limitations apply, the bulletin will instruct users to follow label directions and will provide general information about listed species. For those counties where use limitations do apply, the bulletins will contain a county map showing the geographic area associated with each species of concern. The bulletins will identify the pesticides that jeopardize or involve incidental risk to these species and will describe the use limitations that apply. The bulletins will also contain an address for pesticide users to write to with comments and pertinent information.

The bulletins will be updated, if needed, not more than once annually. Distribution of the bulletins will be through the training and certification programs within the states as well as the county Extension offices, pesticide dealers and distributors, Soil Conservation Service field offices, and the offices of state regulatory agencies.

The Endangered Species Protection Program has been implemented during the 1989 and 1990 growing seasons on a voluntary basis. Presently 17 states are participating in the voluntary program. In January 1991, EPA will implement enforceable measures to protect listed species from pesticides. At that point, EPA will issue Pesticide Registration Notices to the registrants of affected pesticide products to modify the labeling of their products. All affected products released for shipment after a specified date will be required to carry a label statement directing the user of the product to adhere to the limitations in the bulletin.

EPA will implement the program in phases, beginning with a review and update of existing biological opinions. This "catch-up" effort is essential in order to fulfill the agency's legal obligations under the Endangered Species Act with respect to the existing biological opinions.

The second phase will involve consultations on all remaining listed species and registered pesticides. Thereafter, EPA will operate in a "maintenance" phase, evaluating new information, new pesticides or uses, and new species as they are listed. Because EPA is proposing a generic label statement that will not include lists of counties, registrants will not need to change their product labels if use limitations change. Label changes will be necessary only if reasonable and prudent actions are changed for all uses of a product. At present, EPA is proposing to include household products in the program, and they are trying to determine how best to provide homeowners with pertinent information on species and appropriate protective measures.

Importance of Protecting the Endangered Species. Biological diversity is essential for a healthy environment. Removing a single species can directly or indirectly affect many others that rely on it during all or part of its life cycle. It has been estimated, for example, that the disappearance of one plant can take with it 30 other species, including insects, higher animals, and even other plants.

Biologists know that today's danger to wildlife most often results from habitat destruction, environmental pollution, the introduction of nonnative organisms, and exploitation — all generally the direct result of human activity. Scientists also believe that certain pesticides may pose a threat to the survival of some of America's endangered species if used in their remaining habitats.

Pesticide Labels and Safety

Certain precautionary steps should be taken when handling insecticides. The insecticides suggested in this publication can be poisonous to the applicators, the people most likely to suffer ill effects from insecticides. Farmers or applicators are expected to protect themselves, their workers, and their families from needless exposure.

When using insecticides, apply all the scientific knowledge available to make sure that there will be no illegal residue on the marketed crop. Such knowledge is condensed on the label. **Read the label carefully and follow the instructions. The label is the law.** The label should be recent and not from a container several years old. Do not exceed the maximum rates suggested. Observe the interval between application and harvest. Apply only to crops for which use has been approved. Keep records of pesticide use for each field. Record the product used, the trade name, the percentage content of the insecticide, the dilution, the rate of application per acre, and the date or dates of application.

Always handle insecticides with respect. Accidents and careless, needless overexposure can be avoided. Following these rules will prevent most insecticide accidents:

- When using any pesticide, regardless of its toxicity, wear at least a hat, long-sleeved shirt, long-legged trousers or a coverall garment, and socks and shoes.

- Wear rubber boots, rubber gloves, a rubber or vinyl apron, and goggles when handling insecticide concentrates.
- If at all possible, mix insecticides in a place out-of-doors where there are good light and ventilation.
- Keep your face turned to one side when opening, pouring from, or emptying insecticide containers.
- If you splash or spill an insecticide on yourself while mixing or loading, stop immediately, remove contaminated clothing, and wash yourself thoroughly with soap and water.
- Do not smoke, eat, or drink while handling or using insecticides.
- Do not put the water supply hose directly into the spray tank.
- Never leave a spray tank unattended while it is being filled.
- Do not leave puddles of insecticide mixture on impervious surfaces or apply insecticides near dug wells or cisterns.
- Do not blow out clogged nozzles or spray lines with your mouth.
- Avoid spraying near beehives, lakes, streams, pastures, houses, schools, playgrounds, hospitals, or sensitive crops whenever possible. If these areas must be sprayed, do not spray on windy days, and always spray downwind from the sensitive area.
- Do not apply insecticides when drift is likely to occur.
- Do not apply insecticides to fish-bearing or other waters.
- Do not apply insecticides to areas with abundant wildlife.
- To avoid killing bees, apply insecticides early in the morning or late in the evening when bees are not actively foraging. If at all possible, use the insecticide that is least toxic to bees. Before you begin application, warn beekeepers that you are applying insecticides.
- Change clothes and take a shower every day after insecticide application.
- If contamination occurs while using an insecticide, change clothes and shower immediately.
- Keep contaminated clothing away from the family laundry.
- Leave unused insecticides in their original containers with the labels on them.
- If at all possible, buy no more insecticide than you will use, thus eliminating problems with insecticide storage and disposal.
- Store insecticides out of the reach of children, irresponsible persons, and animals, preferably in a locked building marked for insecticide storage. Do not store insecticides near livestock feeds.
- Triple rinse, bury, or burn all empty insecticide containers or take them to an appropriate sanitary landfill.

Refer to the *Illinois Pesticide Applicator Study Guide* for more information concerning safe handling of pesticides and treatment of pesticide poisoning.

Poison Resource Centers

The Poison Resource centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Poison Resource Center will provide first-aid information and refer callers to local treatment centers if necessary.

Poison Resource centers supplement, but do not replace, local emergency medical services. Do not delay calling local emergency medical personnel to request immediate assistance or transportation. If possible, have the pesticide container and label present when you call or reach a treatment center or hospital.

Chicago and northeast Illinois
1753 West Congress Parkway
Chicago, Illinois 60612
Telephone: 800-942-5969

Northern and central Illinois
530 N.E. Glen Oak
Peoria, Illinois 61603
Telephone: 800-322-5330

Central and southern Illinois
800 East Carpenter
Springfield, Illinois 62702
Telephone: 800-252-2022

Soil Insecticides and Seed Treatments

Soil insecticides are often used in corn production to prevent damage by subterranean insects such as corn rootworms, cutworms, seedcorn maggots, white grubs, and wireworms. Seed treatments protect corn and soybean seeds from attack by seedcorn maggots and wireworms. Both soil insecticides and seed treatments are applied as preventive measures because rescue treatments are often ineffective against subterranean insect pests. However, whenever possible, these applications should be made based on scouting information or on the knowledge of frequency of occurrence of the different pests in different cropping sequences. The use of soil insecticides as "insurance" against soil insect pests is strongly discouraged.

In order for soil insecticides to be effective against the target insect you wish to control, proper calibration before application and placement during application are very important. Both the rates of application and placement vary among different soil insecticides for control of the assorted soil insect pests. Tables 4 and 5 list the suggested rates of application and placement for the most frequently encountered soil insect pests of corn. However, before applying soil insecticides, consult the label to determine the appropriate rate and placement for the intended target pest.

Calibration for granular soil insecticides

Calibrate the applicators for granular soil insecticides before the planting season begins. In some instances, poor control is caused by applying rates that are too low. Proper calibration will help avoid this problem. Most soil insecticide bags have a list of suggested settings for the particular model of applicator. The settings are based on planting speed. The *beginning settings* are helpful, but be sure to check your actual application rate under your own operating conditions.

Follow these steps for calibrating the applicator:

1. Calibration of granular applicators for soil insecticides is usually based on ounces of product needed per 1,000 feet of row. Consult the insecticide label or Table 4 for labeled rates for rootworm control. These rates are expressed in ounces per 1,000 feet of row and in pounds of product per acre.
2. Consult the label or manufacturer's recommendation for an approximate application setting. Adjust the setting on each hopper.
3. Select an area for a test run, preferably in the field so that speed and traction conditions are constant. Measure off 1,000 feet.
4. Fill the hoppers and attach a plastic bag or container to each delivery tube to catch the granules from each hopper.
5. Drive the premeasured distance (1,000 feet) at the same speed to be used during the planting operation.
6. Weigh the material collected from each hopper. Use a scale that weighs in ounces (e.g., a postal scale or a diet scale).
7. Compare the weight (ounces) per bag against those given in Table 4. The following amounts of material should be collected:

Formulation, percent	Ounces collected per 1,000 feet
10	12
15	8
20	6

8. Recalibrate if the difference in the amount of insecticide applied during the calibration process is more than 10 percent over or under the rate suggested on the label.

Potential control problems with soil insecticides

A reduction in effectiveness of soil insecticides can be caused by numerous factors, including, but not restricted to, improper application, improper timing of application, dry soil conditions, excessive rainfall or wind moving the insecticide off target, extremely large insect population, enhanced degradation of the insecticide,

Table 4. Soil Insecticides for Rootworm Control, Illinois, 1990

Insecticide[a]	Time of application	Ounces of product per 1,000 ft. of row	Amount of product needed per acre			
			40″ rows	38″ rows	36″ rows	30″ rows
*Aastar G	At planting	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
Broot 15GX	At planting or cultivation	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
*Counter 15G	At planting or cultivation	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
*Counter 20CR	At planting or cultivation	6	5.0 lb.	5.3 lb.	5.6 lb.	6.7 lb.
*Dyfonate II	At planting or cultivation	6	5.0 lb.	5.3 lb.	5.6 lb.	6.7 lb.
*Dyfonate 4E	At planting	2.5 fl. oz.	2 pints	2⅛ pints	2¼ pints	2¾ pints
*Dyfonate 4E	Preplant	Broadcast	3 quarts	3 quarts	3 quarts	3 quarts
*Force 1.5G	At planting	8-10	6.7-8.3 lb.	7.0-8.6 lb.	7.4-9.1 lb.	8.7-10.9 lb.
*Furadan 15G	At planting or cultivation	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
*Furadan 4F	At planting or cultivation	2.5 fl. oz.	2 pints	2⅛ pints	2¼ pints	2¾ pints
Lorsban 15G	At planting or cultivation	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
Lorsban 4E	At cultivation	2.5 fl. oz.	2 pints	2⅛ pints	2¼ pints	2¾ pints
Lorsban 4E	Preplant	Broadcast	6 pints	6 pints	6 pints	6 pints
*Mocap 15G	At planting or cultivation	8	6.7 lb.	7.0 lb.	7.4 lb.	8.7 lb.
*Thimet 20G	At planting or cultivation	6	5.0 lb.	5.3 lb.	5.6 lb.	6.7 lb.

[a] Consult text for more information. LIQUID FORMULATIONS ARE HIGHLY TOXIC.
* Use restricted to certified applicators only.

and insect resistance. Because these products are applied to the soil, usually well before the target insect occurs in the field, they are subjected to numerous environmental and biological forces before they become active against the target pest. Soil insecticides usually provide acceptable insect control under a wide array of conditions. But occasionally growers encounter a lack of control of the target insect by the insecticide they have selected. A recent history of problems with soil insecticides intended to control corn rootworms is a case in point.

Corn rootworm larval control with soil insecticides has been variable in Illinois during the past few years, in both farmers' fields and research trials. Instances of poor control have been observed with all rootworm soil insecticides over a wide geographical area with various soil types and weather conditions. An investigation of some of the problem fields has disclosed several factors that probably contributed to poor control with the insecticides. The factors that stand out but are not easily quantifiable include dry soil conditions during May, June, and July, above-average rootworm larval populations, and improper calibration of equipment (rates that were too low).

In many areas, lack of rain prevented the movement of the insecticide off the granular carrier to the area where rootworm larvae were feeding. Early planting also may have been a contributing factor in some fields because soil insecticides applied in April could have lost much of their potency by the time eggs hatched. Undoubtedly, several of these conditions in combination could have affected the performance of soil insecticides.

Unfortunately the factors that influence the performance of soil insecticides under field conditions are not well understood. Recent research indicates that the breakdown of some soil insecticides by soil microorganisms is accelerated after repeated applications of the same compound. The soil microorganisms use the insecticide as an energy source. As a result, the insecticide has a progressively shorter residual time in the soil. This seems to be most prevalent in fields where the same soil insecticide has been used for several consecutive years; however, the pattern is neither clear-cut nor predictable. In all probability, environmental conditions combined with accelerated degradation of the insecticides are causes for rootworm control problems.

Are the rootworms resistant to the soil insecticides? Although this has not been confirmed, some research data suggest that some slight change in susceptibility has occurred with some compounds. At this point, resistance to insecticides cannot be ruled out, but widespread control failures are not likely caused by resistance.

Because potential control problems can occur through misuse or overuse of soil insecticides, growers should take great care when using these insect control tools in crop production sytems. Soil insecticides should be used only when necessary to prevent damage from a known soil insect pest. Continued use and overapplication of soil insecticides, particularly of the same product, for several consecutive years may cause insect resistance in the target population or accelerated microbial degradation. Soil insecticides should only be used to supplement a complete insect management program that integrates other control alternatives.

Chemical injury to soybeans

There have been instances of phytotoxicity to soybeans when organophosphate soil insecticides were used. The problems have occurred where growers started planting soybeans without first emptying the insecticide boxes. Organophosphate soil insecticides applied in soybean fields treated with Sencor or Lexone may cause injury to a soybean crop, according to information on the labels.

Planter-box seed treatments

Corn. Consider using a seed treatment in fields that do not receive a soil insecticide at planting time. A planter-box seed treatment containing diazinon will protect germinating corn against attack by seedcorn beetles and maggots. A lindane or diazinon + lindane planter-box seed treatment protects seed from attack by seedcorn maggots, seedcorn beetles, and wireworms. Lorsban 50-SL is labeled as a slurry treatment on seed before planting to protect germinating seed against injury by seedcorn maggots and beetles. NOTE: Excess dust from the seed treater may interfere with the electronic monitor in air planters.

Some seed may have already been treated with a combination of insecticide and fungicide. Addition of diazinon + lindane may cause planter units to gum up. Consult your seed or insecticide dealer to obtain specific information about seed treatment combinations.

Soybeans. Consider using a diazinon or diazinon + lindane seed protectant to prevent damage to germinating soybeans from seedcorn maggots. Follow the label directions for application. Potential damage is greatest during cool, wet springs when germination is slow.

Table 5. Insecticides for Field Corn

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworms (True)	*Ambush 2E *Asana XL Dylox 80SP Lorsban 4E malathion 57%EC *Penncap-M *Pounce 3.2EC *Pydrin 2.4EC Sevin XLR Plus	6.4-12.8 oz. 5.8-9.6 oz. 10-20 oz. 1-2 pt. 1½-2 pt. 2-3 pt. 4-8 oz. 5⅓-10⅔ oz. 2-4 pt.	Broadcast	Seedling corn: Control is justified when 25 percent of the plants are being damaged. After pollen shed: Control is justified when the armyworms are eating leaves above ear level.
Billbug	Lorsban 4E	2-3 pt.	Broadcast	Apply as a postemergence rescue treatment with ground equipment.
Chinch bug	*Asana XL Lorsban 4E *Pydrin 2.4EC Sevin XLR Plus	5.8-9.6 oz. 2-3 pt. 5⅓-10⅔ oz. 2-4 pt.	Spray at base of plant.	Treat border rows at the start of migration from small grains. Use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
Corn earworm	*Ambush 2E *Asana XL *Pounce 3.2EC *Pydrin 2.4EC	6.4-12.8 oz. 5.8-9.6 oz. 4-8 oz. 5⅓-10⅔ oz.	Overall spray or directed toward ear zone	Justified only in seed corn fields. Treatments are rarely effective for the control of earworms after worms enter ear tips.
Corn leaf aphid	Cygon 400 Lorsban 4E malathion 57%EC *Penncap-M	⅔-1 pt. 1-2 pt. 1½ pt. 2-3 pt.	On foliage	Apply during late whorl to early tassel when 50% of plants have light to moderate infestations and plants are under drouth stress.
Corn rootworm beetles	*Ambush 2E *Asana XL Cygon 400 Imidan 50WP Lorsban 4E malathion 57%EC *Penncap-M *Pounce 3.2EC *Pydrin 2.4EC Sevin XLR Plus	6.4-12.8 oz. 5.8-9.6 oz. ⅔-1 pt. ½-1 lb. 1-2 pt. 1½ pt. 1-2 pt. 4-8 oz. 5⅓-10⅔ oz. 2 pt.	Overall spray or directed toward ear zone	To protect pollination, treat if there are 5 or more beetles per plant, pollination is not complete, and if silk clipping is observed. Apply Ambush or Pounce prior to the brown silk stage.
Corn rootworm larvae	*Aastar G Broot 15GX *Counter 15G *Counter 20CR *Dyfonate II *Dyfonate 4E *Dyfonate 4E *Force 1.5G *Furadan 15G *Furadan 4F Lorsban 15G Lorsban 4E *Mocap 15G *Thimet 20G	8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 6 oz. per 1,000 ft. row 6 oz. per 1,000 ft. row 6 pt. 2.5 fl. oz. per 1,000 ft. row 8-10 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 2.5 fl. oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 6 pt. 8 oz. per 1,000 ft. row 6 oz. per 1,000 ft. row	Band Band Band, furrow Band, furrow Band Broadcast-PPI[d] Band Band, furrow Band, furrow Band Band Broadcast-PPI[d] Band Band	At planting. Broot 15GX, Counter 15G, Counter 20CR, Dyfonate II, Furadan 15G and 4F, Lorsban 15G and 4E, Mocap 15G, and Thimet 20G can also be applied at cultivation time.

Table 5. Insecticides for Field Corn (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Cutworms	*Ambush 2E	6.4-12.8 oz.	PE[d]	Apply as a postemergence rescue treatment when 3 percent or more of the plants are cut and larvae are still present.
	*Asana XL	5.8-9.6 oz.	PE[d]	
	Lorsban 4E	1-2 pt.	PE[d]	
	*Pounce 3.2EC	4-8 oz.	PE[d]	
	*Pydrin 2.4EC	5⅓-10⅔ oz.	PE[d]	
	*Aastar G	8 oz. per 1,000 ft. row	Band	These preventive treatments are probably best utilized in no-till corn where vegetation was plentiful during the cutworms' egg-laying period, or in fields that have to be replanted because cutworm damage to the original stand was severe.
	*Ambush 2E	6.4-12.8 oz.	PRE[c]	
	*Asana XL	5.8-9.6 oz.	PRE[c]	
	*Dyfonate II	6 oz. per 1,000 ft. row	Band	
	*Force 1.5G	8-10 oz. per 1,000 ft. row	Band, furrow	
	Lorsban 4E	1-2 pt.	PRE[c]	
	Lorsban 4E	2-4 pt.	BC-PPI[c]	
	Lorsban 15G	8 oz. per 1,000 ft. row	Band, furrow	
	*Mocap 15G	8 oz. per 1,000 ft. row	Band	
	*Pounce 1.5G	8-16 oz. per 1,000 ft. row	Band	
	*Pounce 1.5G	6.7-13.3 lb.	PRE[c]	
	*Pounce 3.2EC	4-8 oz.	PRE[c]	
	*Pydrin 2.4EC	5⅓-10⅔ oz.	PRE[c]	
European corn borer, first generation	*Ambush 2E	6.4-12.8 oz.	On upper ⅓ of plant and into whorl	See "Treatment Guidelines" under European Corn Borer, first generation. Granular formulations are more effective than sprays when applied by air for control of first-generation borers. Sprays are most effective when directed by ground equipment over the row, rather than broadcast. Apply Dipel ES only by ground equipment or center pivot irrigation.
	Dipel 10G	10 lb.		
	Dipel ES	2 pt.		
	*Dyfonate II	5 lb.		
	*Furadan 15G	6.7 lb.		
	*Furadan 4F	2 pt.		
	Lorsban 4E	1½-2 pt.		
	Lorsban 15G	5-6.5 lb.		
	*Penncap-M	4 pt.		
	*Pounce 3.2EC	4-8 oz.		
	*Pounce 1.5G	6.7-13.3 lb.		
European corn borer, second generation	*Ambush 2E	6.4-12.8 oz.	On foliage	See "Treatment Guidelines" under European Corn Borer, second generation. Apply Ambush 2E or Pounce 3.2EC prior to the brown silk stage.
	Dipel 10G	10 lb.		
	Dipel ES	2 pt.		
	*Dyfonate II	5 lb.		
	*Furadan 15G	6.7 lb.		
	*Furadan 4F	2 pt.		
	Lorsban 15G	5-6.5 lb.		
	Lorsban 4E	2 pt.		
	*Penncap-M	4 pt.		
	*Pounce 3.2EC	4-8 oz.		
	*Pounce 1.5G	6.7-13.3 lb.		
Fall armyworm	Dylox 80SP	10-20 oz.	On foliage	Treat when 35% of plants have whorl damage and if worms are present. Ground sprays directed over the row are more effective than broadcast sprays. Treatments to control worms in ear tips are not effective.
	Lannate 90WSP	½ lb.		
	Lorsban 4E	2 pt.		
Flea beetles	*Ambush 2E	6.4-12.8 oz.	Over row as spray	When leaves on seedling plants are severely damaged and plants are being killed.
	*Asana XL	5.8-9.6 oz.		
	Lorsban 4E	2 pt.		
	*Penncap-M	2-3 pt.		
	*Pounce 3.2EC	4-8 oz.		
	*Pydrin 2.4EC	5⅓-10⅔ oz.		
	Sevin XLR Plus	2 pt.		
Grasshoppers	*Asana XL	5.8-9.6 oz.	On foliage	Treatment may be warranted when there are 7 or more grasshoppers per square yard. After pollen shed, control is justified when grasshoppers are feeding on leaves above ear level. The higher rates are suggested for control of adult grasshoppers.
	Cygon 400	1 pt.		
	*Furadan 4F	¼-½ pt.		
	Lorsban 4E	½-1 pt.		
	malathion 57%EC	1½ pt.		
	*Penncap-M	1-3 pt.		
	*Pydrin 2.4EC	5⅓-10⅔ oz.		
	Sevin XLR Plus	1-3 pt.		

Table 5. Insecticides for Field Corn (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Japanese beetle	Sevin XLR Plus	2 pt.	On foliage	During the silking period to protect silks if there are 3 or more beetles per ear and pollination is not complete.
Picnic, sap beetles	Lannate 90WSP malathion 57%EC Sevin XLR Plus	¼-½ lb. 1½ pt. 2 pt.	On foliage	Justified only in seed corn fields when beetles are causing significant injury to ear tips.
Seedcorn beetles	diazinon diazinon + lindane Lorsban 50-SL	See label See label See label	On seed On seed On seed	Use formulations that are prepared as seed treaters. See label for proper disposal of treated seeds. Aastar, Counter 15G and 20CR, Dyfonate II, Force 1.5G, Lorsban 20G, and Thimet 20G are also labeled for seedcorn beetle control.
Seedcorn maggots	diazinon diazinon + lindane Lorsban 50-SL	See label See label See label	On seed On seed On seed	Use formulations that are prepared as seed treaters. Seed treatments should be considered for fields that do not receive a soil insecticide at planting. See label for proper disposal of treated seeds. Aastar, Counter 15G and 20CR, Dyfonate II, Force 1.5G, Furadan 15G, Lorsban 15G, and Thimet 20G are also labeled for seedcorn maggot control.
Sod webworm	Lorsban 4E	1-2 pt.	Broadcast	At time of initial attack.
Southwestern corn borer	*Ambush 2E *Dyfonate II *Furadan 15G *Furadan 4F Lorsban 15G Lorsban 4E *Penncap-M *Pounce 3.2EC *Pounce 1.5G	6.4-12.8 oz. 5 lb. 6.7 lb. 2 pt. 6.5 lb. 2 pt. 4 pt. 4-8 oz. 6.7-13.3 lb.	On foliage	Direct granules over row. Apply when 25% of the plants have egg masses or larvae on leaves. Early planted corn usually escapes damage. Sprays are most effective when directed over the row, rather than broadcast. Apply Ambush 2E or Pounce 3.2EC prior to the brown silk stage.
Spider mites	Cygon 400	1 pt.	On foliage	Begin control if the majority of plants are infested with mites severe enough to cause some yellowing or browning of the lower leaves before dent stage.
Stalk borer	*Ambush 2E *Asana XL Lorsban 4E *Pounce 3.2EC *Pydrin 2.4EC	6.4-12.8 oz. 5.8-9.6 oz. 2-3 pt. 4-8 oz. 5⅓-10⅔ oz.	Broadcast	Apply postemergence sprays when young larvae are moving from weed hosts to corn. See labels for more specific instructions about effective control.
Thrips	malathion 57%EC	1½ pt.	On foliage	When severe wilting and yellowing of leaves are noticed.
White grubs	*Aastar G *Counter 15G *Counter 20CR Lorsban 15G Lorsban 4E *Thimet 20G	8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 6 oz. per 1,000 ft. row 8-16 oz. per 1,000 ft. row 4 pt. 6 oz. per 1,000 ft. row	Band Band, furrow Band, furrow Furrow Broadcast-PPI[d] Band	At planting, if crop history and previous crop losses can be directly linked to a repeated history of grub problems. Furadan 15G is labeled to aid in the control of white grubs, and Dyfonate II, Mocap 15G, and Force 1.5G are labeled for their suppression.

Table 5. Insecticides for Field Corn (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Wireworms	*Aastar G	8 oz. per 1,000 ft. row	Band	At planting, if crop history and/or bait stations indicate a potential for wireworm damage. Dyfonate II and Force 1.5G are labeled for suppression of wireworms.
	*Counter 15G	8 oz. per 1,000 ft. row	Band, furrow	
	*Counter 20CR	6 oz. per 1,000 ft. row	Band, furrow	
	*Dyfonate 4E	8 pt.	Broadcast-PPI[d]	
	*Furadan 4F	2.5 oz. per 1,000 ft. row	Furrow	
	*Furadan 15G	8 oz. per 1,000 ft. row	Band, furrow	
	Lorsban 15G	16 oz. per 1,000 ft. row	Band, furrow	
	Lorsban 4E	4 pt.	Broadcast-PPI[d]	
	*Mocap 15G	8 oz. per 1,000 ft. row	Band	
	*Thimet 20G	6 oz. per 1,000 ft. row	Band	
	lindane	See label	On seed	Use formulations that are prepared as seed treaters. See label for proper disposal of treated seeds.
	diazinon + lindane	See label	On seed	
Woollybear caterpillars	None labeled	...	...	Silk clipping caused by caterpillars does not generally warrant control.

* Use restricted to certified applicators only.
[a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.
[c] PPI Preplant incorporated.
[d] PE Postemergent application.
[e] PRE Preemergent application.

Table 6. Insecticides for Soybeans

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Bean leaf beetle	*Ambush 2E	3.2-6.4 oz.	On foliage	**Seedlings:** Treat if 20% of the plants are cut and the stand has gaps of 1 foot or more; or treat if at least 1 seedling per foot of row is destroyed. This level of damage usually requires 5 or more beetles per foot of row. **Before bloom:** when defoliation reaches 30% and there are 5 or more beetles per foot of row. **Bloom to pod fill:** when defoliation reaches 20% and there are 16 or more beetles per foot of row. **Seed maturation:** when 5 to 10% of the pods are damaged, the leaves are green, and there are 10 or more beetles per foot of row.
	*Asana XL	5.8-9.6 oz.		
	Cygon 400	1 pt.		
	Larvin 3.2F	18-30 oz.		
	Lorsban 4E	1-2 pt.		
	Orthene 75S	⅔ lb.		
	*Penncap-M	2-3 pt.		
	*Pounce 3.2EC	2-4 oz.		
	*Pydrin 2.4EC	5⅓ oz.		
	Sevin XLR Plus	1-2 pt.		
Blister beetles	Sevin XLR Plus	1-2 pt.	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Corn earworm	*Ambush 2E	6.4-12.8 oz.	On foliage	Damage occurs when larvae feed on pods. Apply control if populations exceed 1 per foot of row and 5 to 10% of the pods are damaged.
	*Asana XL	5.8-9.6 oz.		
	Larvin 3.2F	10-16 oz.		
	Orthene 75S	1⅓ lb.		
	*Pounce 3.2EC	4-8 oz.		
	*Pydrin 2.4EC	5⅓-10⅔ oz.		
Cutworms	*Asana XL	5.8-9.6 oz.	Broadcast	Scout as plants are emerging. Treat if 20% of plants are cut, stand has gaps of one foot or more, and cutworms are present.
	Larvin 3.2F	20-30 oz.		
	Lorsban 4E	2 pt.		
	*Pounce 3.2EC	2-4 oz.		
	*Pydrin 2.4EC	5⅓-10⅔ oz.		

Table 6. Insecticides for Soybeans (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Grasshoppers	*Asana XL Cygon 400 *Furadan 4F Lorsban 4E Orthene 75S *Penncap-M *Pydrin 2.4EC Sevin XLR Plus	5.8-9.6 oz. 1 pt. ¼-½ pt. ½-1 pt. ⅓-⅔ lb. 1-3 pt. 5⅓-10⅔ oz. 1-3 pt.	On foliage	When migration into fields begins and defoliation or pod feeding reaches economic levels. When defoliation reaches 30% before bloom and 20% between bloom and pod fill. When 5 to 10% of the pods are damaged. The higher rates are suggested for control of adult grasshoppers.
Green clover-worm	*Ambush 2E *Asana XL Dipel Larvin 3.2F Lorsban 4E Orthene 75S *Penncap-M *Pounce 3.2EC *Pydrin 2.4EC Sevin XLR Plus	3.2-6.4 oz. 2.9-5.8 oz. See label 10-16 oz. ½-1 pt. ⅔ lb. 2-3 pt. 2-4 oz. 2⅔-5⅓ oz. 1-2 pt.	On foliage	When defoliation occurs during blooming, pod set, and pod fill. Usually requires 12 or more half-grown worms per foot of row and 20% defoliation to justify treatment.
Japanese beetle adults	*Asana XL *Penncap-M *Pydrin 2.4EC Sevin XLR Plus	5.8-9.6 oz. 3-4 pt. 5⅓-10⅔ oz. 2 pt.	On foliage	When defoliation reaches 20% during bloom and pod fill.
Loopers	*Ambush 2E *Asana XL Larvin 3.2F Orthene 75S *Pounce 3.2EC *Pydrin 2.4EC Dipel	3.2-6.4 oz. 5.8-9.6 oz. 18-30 oz. ⅔-1⅓ lb. 2-4 oz. 5⅓-10⅔ oz. See label	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Mexican bean beetle	*Ambush 2E *Asana XL Cygon 400 *Furadan 4F Larvin 3.2F Lorsban 4E Orthene 75S *Penncap-M *Pounce 3.2EC *Pydrin 2.4EC Sevin XLR Plus	3.2-6.4 oz. 2.9-5.8 oz. 1 pt. 1 pt. 18-30 oz. 1 pt. ⅔ lb. 2-3 pt. 2-4 oz. 2⅔-5⅓ oz. 1-2 pt.	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Potato leafhopper	*Ambush 2E *Asana XL Cygon 400 *Penncap-M *Pounce 3.2EC *Pydrin 2.4EC Sevin XLR Plus	3.2-6.4 oz. 2.9-5.8 oz. 1 pt. 2-3 pt. 2-4 oz. 2⅔-5⅓ oz. 2 pt.	On foliage	When leafhoppers are numerous and the edges of the leaves appear burned.
Seedcorn maggot	diazinon diazinon + lindane	See label See label	On seed On seed	At planting time. Use formulations that are prepared as seed treaters. See label for proper disposal of treated seeds.
Spider mites	Cygon 400 Dimethoate 400 Lorsban 4E	1 pt. 1 pt. ½-1 pt.	On foliage	When symptoms of injury appear and mites are present.
Stink bugs	*Asana XL Lorsban 4E Orthene 75S *Penncap-M *Pydrin 2.4EC	5.8-9.6 oz. 2 pt. 1-1⅓ lb. 2-3 pt. 5⅓-10⅔ oz.	On foliage	When adult bugs or large nymphs reach 1 per foot of row during pod fill.

Table 6. Insecticides for Soybeans (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Thistle caterpillar	Sevin XLR Plus	3-4 pt.	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Thrips	*Penncap-M Sevin XLR Plus	2-3 pt. 2 pt.	On foliage	If seedlings are being seriously damaged and some plants are being killed.
Webworms	Sevin XLR Plus	2-3 pt.	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Whitefly	None labeled	...	...	High infestations are occasionally present on double-crop soybeans, but are rarely economic.
Woollybear caterpillars	*Ambush 2E *Asana XL Larvin 3.2F Lorsban 4E *Pounce 3.2EC *Pydrin 2.4EC	3.2-6.4 oz. 2.9-5.8 oz. 10-16 oz. 1-2 pt. 4 oz. 2⅔-5⅓ oz.	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.

* Use restricted to certified applicators only. [a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.

Spraying blossoming soybeans can be extremely hazardous to bees. Coordinate with local beekeepers before applying sprays. Beekeepers' names and colony locations may be obtained from your County Extension Office.

Table 7. Insecticides for Alfalfa
To avoid injury to bees, do not spray alfalfa during bloom or if weeds are blooming.

Insect	Insecticide[a,b,c]	Amount of product per acre[c]	Placement	Timing of application, comments
Alfalfa caterpillar	*Ambush 2E Dipel Dylox 80SP *Pounce 3.2EC Sevin XLR Plus	3.2-12.8 oz. See label 8-10 oz. 2-8 oz. 2 pt.	On foliage	When damage to foliage is obvious and there are at least 10 nonparasitized larvae per sweep.
Alfalfa weevil (spring treatment for larvae)	*Ambush 2E *Furadan 4F Imidan 50WP Lorsban 4E[d] *Penncap-M *Pounce 3.2EC *Supracide 2E	12.8 oz. ½-1 pt. 2 lb. 2 pt. 2-3 pt. 8 oz. 2 pt.	On foliage	Refer to Circular 1136. Or when 25% to 40% of tips are being skeletonized and if there are 3 or more larvae per stem, treat immediately. Do not apply sprays during bloom. Instead, cut and remove the hay. Two treatments may be necessary on first cutting. Control may also be warranted after a cutting when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3 to 6 days.
Alfalfa weevil adults	*Furadan 4F Imidan 50WP Lorsban 4E[d] *Penncap-M	1-2 pt. 2 lb. 1-2 pt. 2-3 pt.	On foliage	Control may be warranted after a cutting when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3 to 6 days.
Aphids	*Ambush 2E Cygon 400 *Furadan 4F Lorsban 4E[d] malathion 57%EC *Penncap-M *Pounce 3.2EC *Supracide 2E	3.2-12.8 oz. ½-1 pt. ½ pt. ½ pt. 1½ pt. 2 pt. 2-8 oz. 2 pt.	On foliage	When aphids average 100 or more per sweep and lady beetle larvae and adults, parasites, and diseases are not abundant.

Table 7. Insecticides for Alfalfa (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Blister beetles	Sevin XLR Plus	1-2 pt.	On foliage	Although blister beetles rarely cause economic damage to alfalfa, their presence in hay could injure horses if the horses ingest the beetles.
Cutworms	*Ambush 2E	3.2-12.8 oz.	On foliage	Control may be warranted when larvae reduce the stand of a new seeding or prevent regrowth after harvest.
	Dylox 80SP	10-20 oz.		
	Lorsban 4E[d]	2 pt.		
	*Pounce 3.2EC	2-8 oz.		
	Sevin XLR Plus	2-3 pt.		
Fall armyworm	Dylox 80SP	20 oz.	On foliage	Control may be warranted when larvae reduce the stand of a new seeding, when there are 2 or more larvae per sweep, or when there are 1 to 2 half-grown larvae per square foot.
	Lorsban 4E[d]	2 pt.		
	Sevin XLR Plus	2 pt.		
Grasshoppers	Cygon 400	½-1 pt.	On foliage	When grasshoppers are small, before damage is severe, and there are 15 to 20 per square yard. The higher rates are suggested for control of adult grasshoppers.
	*Furadan 4F	¼-½ pt.		
	Imidan 50WP	3-4 lb.		
	Lorsban 4E[d]	½-1 pt.		
	*Penncap-M	1-3 pt.		
	Sevin XLR Plus	1-3 pt.		
Leafhoppers	*Ambush 2E	3.2-12.8 oz.	On foliage	Treatment is justified at these combinations of alfalfa height and leafhopper numbers: Alfalfa height (inches) — Leafhoppers per sweep 0-3 — 0.2 3-6 — 0.5 6-12 — 1.0 12 or taller — 1.5
	Cygon 400	½-1 pt.		
	Dylox 80SP	10-20 oz.		
	*Furadan 4F	1 pt.		
	Imidan 50WP	2 lb.		
	Lorsban 4E[d]	1-2 pt.		
	*Penncap-M	2-3 pt.		
	*Pounce 3.2EC	2-8 oz.		
	Sevin XLR Plus	2 pt.		
	*Supracide 2E	2 pt.		
Plant bugs	*Ambush 2E	6.4-12.8 oz.	On foliage	When tip damage is obvious and nymphs and adults average 3 per sweep on alfalfa less than 3 inches tall, or 5 per sweep on alfalfa taller than 3 inches.
	Cygon 400	½-1 pt.		
	Dylox 80SP	20 oz.		
	*Furadan 4F	2 pt.		
	Lorsban 4E[d]	1-2 pt.		
	*Penncap-M	2-3 pt.		
	*Pounce 3.2EC	4-8 oz.		
	Sevin XLR Plus	2 pt.		
Spittlebug	*Ambush 2E	6.4-12.8 oz.	On foliage	When spittle masses are found and nymphs average more than 1 per stem.
	Imidan 50WP	2 lb.		
	Lorsban 4E[d]	1-2 pt.		
	malathion 57%EC	1½ pt.		
	*Penncap-M	2-3 pt.		
	*Pounce 3.2EC	4-8 oz.		
Webworms	*Ambush 2E	3.2-12.8 oz.	On foliage	Control may be warranted when larvae reduce the stand of a new seeding.
	Dylox 80SP	20 oz.		
	*Pounce 3.2EC	2-8 oz.		
	Sevin XLR Plus	2-3 pt.		

* Use restricted to certified applicators only. [a] See Table 12 for insecticide restrictions.
[b] Before applying insecticides, be certain to clean all herbicides out of equipment. During bloom, apply very late in day or, if possible, avoid application during bloom.
[c] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.
[d] Young, tender, rapidly growing alfalfa may show some phytotoxic symptoms when treated with Lorsban 4E.

Spraying blossoming alfalfa can be extremely hazardous to bees. Coordinate with local beekeepers before applying sprays. Beekeepers' names and colony locations may be obtained from your County Extension Office.

Table 8. Insecticides for Grain Sorghum

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Chinch bug	Lorsban 4E[c] Sevin XLR Plus	2 pt. 2-4 pt.	At plant base	Use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
Corn earworm	Lannate 90WSP Lorsban 4E Sevin XLR Plus	¼-½ lb. 2 pt. 2-4 pt.	Over row	When there is an average of 2 worms per head.
Corn leaf aphid	Cygon 400 Lorsban 4E[c] malathion 57%EC	½-1 pt. ½-1 pt. 1½ pt.	Over row	Corn leaf aphids rarely cause economic damage unless populations are heavy and drouth conditions exist.
Cutworms	Lorsban 4E[c] Sevin XLR Plus	2 pt. 4 pt.	Broadcast Broadcast	When seedling plants are being cut.
Fall armyworm	Lannate 90WSP Lorsban 4E[c]	¼-½ lb. 2 pt.	Over row	When there is an average of 2 worms per head. Leaf feeding or whorl damage is seldom economic.
Grasshoppers	Cygon 400 Lorsban 4E[c] Sevin XLR Plus	1 pt. ½-1 pt. 1-3 pt.	Over row	Treatment may be warranted when there are 7 or more per square yard. The higher rates are suggested for control of adult grasshoppers.
Greenbug	Cygon 400 Lorsban 4E[c] malathion 57%EC	½-1 pt. ½-1 pt. 1½ pt.	Over row	When greenbug damage is sufficient to cause death of more than 2 normal-sized leaves before the hard-dough stage. CAUTION: Some sorghum varieties are sensitive to organophosphate insecticides.
Sorghum midge	Lorsban 4E[c] Sevin XLR Plus	½ pt. 1½-2 pt.	Over row	Apply during bloom when 50% of heads have begun to bloom and there are 1 or more midge adults (flies) per head.
Webworms	Lorsban 4E[c] Sevin XLR Plus	2 pt. 2-4 pt.	Over row	When 5 or more larvae per head are found.
White grubs	*Counter 15G *Counter 20CR	8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row	Band Band	At planting, if crop history and previous crop losses can be directly linked to a repeated history of grub damage.
Wireworms	*Counter 15G *Counter 20CR *Furadan 15G	8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row 8 oz. per 1,000 ft. row	Band Band Furrow	At planting, if crop history and/or bait stations indicate a potential for wireworm damage.
	lindane	See label	On seed	Use seed treatment formulations. See label for proper disposal of treated seeds.
Yellow sugar-cane aphid	Cygon 400 Lorsban 4E[c]	1 pt. ½-1 pt.	Over row	Sprays should be applied at first sign of damage to seedling sorghum; 5 to 10 aphids per leaf.

* Use restricted to certified applicators only.
[a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.
[c] To avoid phytotoxicity, do not treat plants that are under extreme heat and drouth stress.

Table 9. Insecticides for Small Grains (Barley, Oats, Rye, Wheat)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworm	Lannate 90WSP *Penncap-M Sevin XLR Plus	¼-½ lb. 2-3 pt. 2-3 pt.	On foliage	When there are 6 or more nonparasitized armyworms (¾-1¼ inch long) per linear foot of row and before extensive head cutting occurs. Do not use Penncap-M on rye.
Cereal leaf beetle	*Furadan 4F Lannate 90WSP malathion 57%EC Sevin XLR Plus	½ pt. ¼-½ lb. 1½ pt. 2 pt.	On foliage	When there are one or more small larvae per stem or flag leaf. Apply Furadan before heads emerge from the boot.

Table 9. Insecticides for Small Grains (Barley, Oats, Rye, Wheat) (continued)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Fall armyworm	Sevin XLR Plus	2-3 pt.	On foliage	During fall when damage to new growth is apparent.
Grasshoppers	Cygon 400 *Furadan 4F malathion 57%EC *Penncap-M Sevin XLR Plus	¾ pt. ¼-½ pt. 1½ pt. 1-3 pt. 1-3 pt.	On foliage	During fall when damage is apparent, treat field borders and noncrop areas to stop migration. The higher rates are suggested for control of adult grasshoppers. Do not apply Penncap-M to rye.
Greenbug, English grain aphid, oat bird-cherry aphid	Cygon 400 Lannate 90WSP malathion 57%EC *Penncap-M	½-¾ pt. ¼-½ lb. 1½ pt. 1-2 pt.	On foliage	Aphids damage plants indirectly by transmitting disease. Once yellowing is noticeable, it is usually too late to treat. Use Cygon on wheat only. Do not apply Penncap-M to rye.
Wheat stem maggot	None	. .	. . .	No chemical control. Damage shows as white heads when field is still green.

* Use restricted to certified applicators only.
[a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.

Table 10. Insecticides for Grass Pasture

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworms	malathion 57%EC *Penncap-M Sevin XLR Plus	2 pt. 2-3 pt. 2-3 pt.	On foliage	Do not apply when weeds are blooming.
Grasshoppers	malathion 57%EC *Penncap-M Sevin XLR Plus	1½ pt. 1-3 pt. 1-3 pt.	On foliage	When there are 15 to 20 per square yard. The higher rates are suggested for control of adult grasshoppers. Do not apply when weeds are blooming.

* Use restricted to certified applicators only.
[a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.

Table 11. Insecticides for Noncrop Areas

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Grasshoppers	*Asana XL Imidan 50WP malathion 57%EC *Penncap-M *Pydrin 2.4EC Sevin XLR Plus	2.9-5.8 oz. 3-4 lb. 1½ pt. 1-3 pt. 2⅔-5⅓ oz. 1-3 pt.	On foliage	When grasshopper nymphs average 15 to 20 per square yard along roadsides and fence rows. Apply treatments while hoppers are small and before they migrate into row crops. The higher rates are suggested for control of adult grasshoppers. Do not spray areas adjacent to water or where runoff is likely to occur.

* Use restricted to certified applicators only. [a] See Table 12 for insecticide restrictions.
[b] The formulation of the product most commonly used in Illinois is listed. If you use another formulation, READ THE LABEL to determine the amount of product per acre.

To avoid injury to bees, do not apply sprays to noncrop areas if weeds are blooming.

Table 12. Harvest Restrictions: Limitations in Days between Application of the Insecticide and Harvest of Crop and Restrictions on Use of Insecticides for Field Crop Insect Control (These are only guidelines. Read the label for more detailed information.)

(Blanks denote that the product may not be labeled or suggested for that specific use in Illinois)

	Field corn			Forage crops		
Insecticide	Grain	Ensilage	Grain Sorghum	Alfalfa	Clover	Pasture
*Aastar G (phorate + flucythrinate)	A	60	...	...	...	...
*Ambush 2E, 25W (permethrin)[a,b]	B	B	...	C	...	...
*Asana XL (esfenvalerate)	21,D	21,D	...	...	...	...
Broot 15GX (trimethacarb)	90	90	...	...	...	...
*Counter 15G, 20CR (terbufos)	E	30,E	F	...	...	...
Cygon 400 (dimethoate)[b]	14,G	14,G	28,G	10,H	...	...
Diazinon AG 500	A	A	7	10	10	0
Dipel (*Bacillus thuringiensis*)	A	A	...	...	...	...
*Dyfonate II, 4E (fonofos)[a,b]	30	30	...	...	...	...
Dylox 80SP (trichlorfon)	I	I	...	0,I	0,I	...
*Force 1.5G (tefluthrin)	J	J	...	...	...	...
*Furadan 15G, 4F (carbofuran)[a,b]	30,K,L	30,K,L	75	M	...	...
Imidan 50WP (phosmet)	14	14	...	7,H	...	...
Lannate 90WSP (methomyl)[a,b]	A	3	14	...	...	...
Lorsban 15G, 4E (chlorpyrifos)	35,N	14,N	60,P	21,Q	...	...
Malathion 57% EC	5	5	7	0	0	0
*Mocap 15G (ethoprop)	A	A	...	...	...	...
*Penncap-M (microencapsulated methyl parathion)[a,b]	12	12	...	15	...	15
*Pounce 3.2EC, 25WP, 1.5G (permethrin)[a,b]	R	R	...	C	...	...
*Pydrin 2.4EC (fenvalerate)[a,b]	21,S	21,S	...	...	...	...
Sevin XLR Plus (carbaryl)	0	0	21	7	0	5,T
*Supracide 2E (methidathion)[a,b]	...	...	...	10,U	...	...
*Thimet 20G (phorate)	30,V	30,V	...	...	...	...

Insecticide	Barley	Oats	Rye	Wheat	Soybeans	Sunflowers
*Ambush 2E, 25W (permethrin)[a,b]	...	...	...	...	60,W	...
*Asana XL (esfenvalerate)	...	...	...	...	21,X	...
Cygon 400 (dimethoate)[b]	...	...	...	60	21	...
Dipel, Thuricide, Bactur, SOK (*Bacillus thuringiensis*)	...	...	...	...	0	...
*Furadan 15G, 4F (carbofuran)[a,b]	Y	Y	...	Y	21,Z	28,AA
Lannate 90WSP (methomyl)[a,b]	7	7	7	7	...	...
Larvin 3.2F (thiodicarb)	...	...	...	...	28,BB	...
Lorsban 15G, 4E (chlorpyrifos)	...	...	...	...	28,CC	42,DD
Malathion 57% EC	7	7	7	7	0	...
Orthene 75S (acephate)	...	...	...	...	14,BB	...
*Penncap-M (microencapsulated methyl parathion)[a,b]	15	15	...	15	20,EE	...
*Pounce 3.2EC, 25WP (permethrin)[a,b]	...	...	...	...	60,W	...
*Pydrin 2.4EC (fenvalerate)[a,b]	...	...	...	...	21,FF	28,FF
Sevin XLR Plus (carbaryl)	...	...	...	21	0	60
*Supracide 2E (methidathion)[a,b]	...	...	...	...	...	50,BB

Read the label for more detailed information.

A. No specific restriction when used as recommended.

B. Apply prior to the brown silk stage.

C. Do not apply more than 0.2 pound active ingredient per cutting. When rates of 0.1 pound active ingredient per acre or less are used, application may be made on day of harvest. When rates greater than 0.1 pound active ingredient per acre are used, do not apply within 14 days of harvest. For aerial application, do not apply within 100 yards of aquatic habitats. For ground application, do not apply within 20 yards of aquatic habitats.

D. Do not exceed 0.25 pound of active ingredient per acre per season for field and seed corn. Do not exceed 0.5 pound of active ingredient per acre per season for popcorn.

E. Only one at planting, postemergence incorporated, or cultivation time treatment of Counter may be used.

F. Only one application per year may be used.

G. Make no more than 3 applications per year. Do not apply to corn during the pollen-shed period if bees are actively foraging in the treated area. Do not apply to sorghum after heading.

H. Apply only once per cutting; do not apply during bloom.

I. Three applications may be made per season on corn, and 3 applications may be made per cutting of alfalfa or grasses. Can be applied up to harvest.

J. Do not rotate to crops other than soybeans or corn. Soybeans may be planted 12 months after Force application. For ground application, do not apply this product within 20 yards of water (ponds, streams or lakes).

K. Do not make a foliar application if Furadan 15G was applied at more than 8 ounces per 1,000 linear feet of row (6.7 pounds per acre with 40-inch row spacing) at planting. Do not make more than 2 foliar applications of Furadan 15G per season.

L. Do not make more than 2 applications of Furadan 4F per season at the 1½ to 2-pint use rate. Do not make more than 4 applications per season at the 1-pint use rate. Do not apply Furadan 4F on seed corn less than 14 days prior to detasseling or rogueing. If prolonged, intimate contact with corn or sorghum foliage will result, do not reenter treated field within 14 days of application without wearing proper clothing. For all other situations do not reenter fields less than 24 hours following application unless appropriate clothing is worn.

M. Make no more than 2 applications per season. Do not apply more than twice per season. Do not apply more than once per cutting. Do not use more than 1 pint per acre in the second application. Apply only to fields planted to pure stands of alfalfa. When using no more than ¼ pound per acre, allow 7 days between application and harvest. When using ¼ to ½ pound per acre, allow 14 days between application and harvest. When using ½ to 1 pound per acre, allow 28 days between application and harvest. Do not move bees to alfalfa fields within 7 days of application.

N. For soil insect control, do not exceed the equivalent of 16 ounces of Lorsban 15G per 1,000 feet of row or 13.5 pounds of Lorsban 15G per acre per crop season. For foliar insect control, do not exceed the equivalent of 16 ounces of Lorsban 15G per 1,000 feet of row or 13 pounds of Lorsban 15G per acre per crop season. Do not apply more than a total of 15 pints of Lorsban 4E per acre per season. Do not allow livestock to graze in treated areas nor harvest treated corn silage as feed for meat or dairy animals within 14 days after last treatment. Do not feed treated corn fodder to meat or dairy animals within 35 days after last treatment.

P. The treated crop is not to be used for forage, fodder, hay, or silage within 30 days after application of 1 pint of Lorsban 4E per acre or within 60 days after application of rates above 1 pint per acre. Do not treat sweet varieties of sorghum. Do not apply more than 3 pints of Lorsban 4E per acre per season. Do not make more than one application of Lorsban 15G per season.

Q. Do not apply more than once per cutting. Do not cut or graze treated alfalfa within 7 days of application of ½ pint of Lorsban 4E per acre, within 14 days after application of 1 pint per acre, or within 21 days after application of rates above 1 pint per acre. Do not make more than 4 applications per year.

R. Apply Pounce 3.2EC prior to the brown silk stage. Do not apply more than 0.4 pound active ingredient of Pounce 1.5G per acre after the brown silk stage. Do not exceed a total of 1.0 pound active ingredient per acre per season.

S. Do not exceed 1.0 pound of active ingredient per acre per season for field and seed corn. Do not exceed 2 pounds of active ingredient per acre per season for popcorn.

T. Do not allow foraging and do not cut for hay within 14 days of last application by ground. Aerially treated pastures may be grazed or cut for hay on the day of treatment. Apply a maximum of 2 applications per year. Allow at least 14 days between applications.

U. Make no more than 1 foliage and 1 stubble application per alfalfa cutting.

V. Do not make more than one application over the plant.

W. Do not graze or feed soybean forage or hay. Do not apply more than 0.4 lb. active ingredient per acre per season.

X. Do not feed or graze livestock on treated plants. Do not exceed 0.2 pound of active ingredient per acre per season.

Y. Apply before heads emerge from boot. Do not make more than 2 applications per season. Do not feed treated forage to livestock.

Z. Do not use Furadan 4F as a foliar application if Furadan 10G, Furadan 15G, or Furadan 4F was applied to soybeans at planting time. Do not make more than 2 foliar applications per season. Do not graze or feed foliar-treated forage to livestock or cut for silage or hay.

AA. No more than 4 applications per season.

BB. Do not graze or feed treated crop to livestock.

CC. Do not apply more than 6 pints of Lorsban 4E per acre or 3 pounds of chlorpyrifos (active ingredient) per acre per season. Do not apply last treatment within 28 days before harvest or apply last 2 treatments closer than 14 days apart. Do not allow livestock to graze in treated areas or otherwise feed treated soybean forage, hay, and straw to meat or dairy animals. On determinate soybeans do not apply more than one application after pod set.

DD. Do not apply more than 9 pints of Lorsban 4E per acre per season. Do not allow livestock to graze in treated areas.

EE. Do not make more than 2 applications per season.

FF. Do not feed or graze livestock on treated plants. Do not exceed 0.8 pound active ingredient per acre per season.

* Use restricted to certified applicators only.

[a] Workers should be warned in advance of treatments. Workers may not enter fields treated with the insecticides without wearing protective clothing for the intervals indicated. They may not enter a field treated with other insecticides without protective clothing until the spray has dried or the dust has settled. Protective clothing includes a hat, long-sleeved shirt, full length pants, and shoes and socks.

[b] Sprays to be applied only by experienced operators wearing proper protective clothing.

Table 13. Relative Toxicities of Commonly Used Agricultural Insecticides

Trade name	Chemical class[b]	Chemical name	Toxicity to mammals[a] Acute oral	Acute dermal	Toxicity to Birds	Fish	Bees
*Aastar	OP,P	Phorate + flucythrinate	high	high	moderate	very high	moderate
*Ambush	P	permethrin	low	low	low	very high	high
*Asana	P	esfenvalerate	moderate	low	low	very high	high
Broot	C	trimethacarb	moderate	low	moderate	moderate	. . .
*Counter	OP	terbufos	high	high	high	very high	. . .
Cygon	OP	dimethoate	moderate	moderate	moderate	very low	very high
Diazinon	OP	diazinon	moderate	moderate	high	high	high
Dipel, Bactur, Topside, Thuricide, SOK	. . .	*Bacillus thuringiensis*	very low	very low	very low	very low	very low
*Dyfonate	OP	fonofos	high	moderate	high	very high	. . .
Dylox	OP	trichlorfon	low	low	low	very low	low
*Force	P	tefluthrin	low	low	low	very high	low
*Furadan	C	carbofuran	high	moderate	high	moderate	high
Imidan	OP	phosmet	moderate	low	moderate	moderate	very high
Lannate WSP	C	methomyl	high	moderate	low	moderate	high
Larvin	C	thiodicarb	moderate	low	low	moderate	moderate
Lorsban	OP	chlorpyrifos	moderate	moderate	moderate	very high	high
Malathion	OP	malathion	low	low	low	moderate	high
*Mocap	OP	ethoprop	moderate	high	moderate	. . .	moderate
Orthene	OP	acephate	moderate	moderate	moderate	low	high
*Penncap-M	OP	microencapsulated methyl parathion	moderate	low	moderate	very low	high
*Pounce	P	permethrin	low	low	low	very high	high
*Pydrin	P	fenvalerate	moderate	low	low	very high	very high
Sevin	C	carbaryl	low	low	very low	very low	high
*Supracide	OP	methidathion	high	moderate	moderate	high	high
*Thimet	OP	phorate	high	high	moderate	very high	moderate

* Use restricted to certified applicators only.
[a] Relative toxicities based on acute oral and acute dermal LD_{50} values of technical insecticide. Toxicities of formulated materials vary.
[b] OP = organophosphate, P = pyrethroid, C = carbamate.

Always read the label before applying insecticides.

WORKER REENTRY PERIODS IN FIELDS WHERE INSECTICIDES HAVE BEEN APPLIED

Most insecticide labels contain a statement about the length of time that should elapse before a person enters a treated field. The following is a summary of minimum field reentry times for insecticides commonly used in field crops. Follow label directions and do not enter treated fields without protective clothing until the reentry period has passed. Protective clothing is defined on most insecticide labels as a hat or other suitable head covering, a long-sleeved shirt and long-legged trousers or a coverall type garment, shoes, and socks.

Table 14. Worker Reentry Periods in Fields Where Insecticides Have Been Applied

Insecticide	Reentry statement on label
Aastar G	Do not enter treated areas without protective clothing until treatments have been completed.
Ambush 2E	Wait until spray is dry.
Asana XL	After spray has dried.
Broot 15GX	After dust has settled in treated field.
Counter 15G, 20CR	Do not enter treated areas without protective clothing until treatments have been completed.
Cygon 400	Wait four days, unless protective clothing is worn.
Diazinon AG 500	After spray is dry.
Dyfonate 4EC	Wait 24 hours, unless protective clothing is worn.
Dyfonate II 20G	Wait 24 hours, unless protective clothing is worn.
Force 1.5G	None specified on table.
Furadan 4F Furadan 15G	If prolonged intimate contact with corn and sorghum will result, do not reenter treated field within 14 days without proper protective clothing. For all other situations, do not reenter field less than 24 hours following application.
Imidan 50W	After spray has dried.
Lannate 90WSP	After spray has dried.
Larvin 3.2F	After spray has dried.
Lorsban 4E	Wait 24 hours, unless protective clothing is worn.
Lorsban 15G	None specified on label.
Malathion 57EC	After spray has dried.
Mocap 15G	After chemical has been mixed in soil.
Orthene 75SP	After spray has dried.
Penncap-M	Wait 48 hours.
Pounce 1.5G	None specified on label.
Pounce 3.2EC	After spray has dried.
Pydrin 2.4EC	After spray has dried.
Sevin XLR Plus	After spray has dried.
Supracide 2E	Wait 48 hours.
Thimet 20G	Do not enter treated areas without protective clothing until soil treatment is completed; 7 days for foliar application.

1990 Insect Pest Management Guide HOME, YARD, and GARDEN

MUCH HAS BEEN SAID ABOUT THE EFFECTS of pesticides, particularly insecticides, on the health and well-being of the American people. However, as you are also aware, insects can destroy your property or make your life uncomfortable. Destruction of crop residues, varietal selection, handpicking, fertilization, tree pruning, irrigation, screening, and other practices may reduce the number of insects with which you must contend. Occasionally, you can avoid or at least reduce the destruction caused by some pests without using an insecticide. For many insects, though, you must rely on an insecticide to provide the satisfactory management you want.

SAFE USE OF INSECTICIDES

By using insecticides and other pest-management tools carefully, you can enjoy reasonable freedom from insects without endangering yourself, your family, or your pets. You must recognize, however, that insecticides are designed to destroy one group of animals — insects — and can be harmful to other animals, including humans, if used without regard for normal safety precautions. Each insecticide user must handle, apply, and store insecticides safely in order to benefit from them without suffering from their dangers.

This publication lists certain insecticides with which to control insect pests of food, fabrics, structures, humans and animals, lawns, shrubs, trees, flowers, and vegetables. We have tried to suggest only the safest and most available materials. You may prefer to employ the services of a professional exterminator or custom applicator rather than to become involved in the selection and application of insecticides.

INSECTICIDES AND THEIR NAMES

The names used in the tables are the common, coined chemical names, not the trade names, and as such may not be familiar to you. For instance, the common name for *Cygon* is *dimethoate*. If there is no coined chemical name, the trade name is used but is capitalized. A table giving common, trade, and chemical names appears at the end of this circular.

CLASSIFICATION OF INSECTICIDES

Insecticides are being classified for *general use* or *restricted use* by the U.S. Environmental Protection Agency. Only a few insecticides have been classified for restricted use at this time. No insecticides in this circular, except those listed for termites, have a restricted-use classification. A person wishing to use an insecticide classified for restricted use must be certified as a private or commercial applicator by the State of Illinois. Contact your county Extension adviser in agriculture for details about that program.

Requested label clearances for a few uses of some insecticides, carriers, and solvents are uncertain for 1990, since many requests have not yet been officially cleared. Consequently, labels may be cancelled, and the product removed from the market at any time. Anticipating this, we took a conservative attitude a few years ago and began modifying suggested uses in these annually revised guides. We have attempted to anticipate any further label changes in 1990, but occasionally there are still use cancellations. Check with your local county Extension adviser if you are not sure about the insecticide you plan to use. We will make announcements about label changes through the news media and newsletters in an attempt to keep you up to date.

Suggestions for the use of insecticides, effective from a practical standpoint, are based on available data. Many factors affect efficiency of control. Please report details of control failures to us.

In using the tables in this circular, *always read the footnotes* before using the insecticides. The footnotes list precautions and other pertinent information.

The suggestions given in this circular are subject to change without notification during the year.

SOURCES OF INFORMATION ON INSECTS

Fact sheets describing the life history, habits, and damage of specific insects and the nonchemical methods of control can be obtained from your county Extension adviser or by writing to Entomology Extension, 172 Natural Resources Building, 607 E. Peabody Drive, Champaign, Illinois 61820. These fact sheets are indicated by an NHE number in the tables.

INTEGRATED PEST MANAGEMENT FOR HOMEOWNERS

Pest control should be conducted in as safe a manner as possible. Reducing the use of insecticides and other pesticides through integrated pest management (IPM) is one way to accomplish this goal. The two main components of IPM are scouting for pests and utilization

Prepared by Roscoe Randell, Philip Nixon, and Fredric Miller, Jr., Extension Entomologists
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
In cooperation with ILLINOIS NATURAL HISTORY SURVEY CIRCULAR 900-90 (revised annually) October 1989

of a variety of pest population control methods. These include mechanical, biological, cultural, and chemical tools, use of resistant varieties, and prevention.

Scouting

Scouting is the process of finding the suspected pest, identifying it, and determining whether the pest is present in great enough numbers to justify control.

Finding the suspected pest. Indirect evidence may or may not indicate the presence of a pest. For instance:

— Holes in leaves may be caused by late frost damage, not by chewing insects.

— Piles of sawdust in the home may be construction debris sifting through cracks or the consequence of mouse activity rather than the trail of carpenter ants or other wood-destroying insects.

It is important to find the insects or other pests actually responsible for the damage observed. Do not assume guilt through association with the damage.

Identification. Once found, the suspect pest must be identified. In some situations an insect that is present in great numbers may not be the cause of damage.

— Lady beetle larvae and adults and other aphid-destroying insects are often found in large numbers in the midst of damage caused by aphids.

— Large numbers of ants in the lawn rarely damage the lawn and have little relationship to the number of ants that enter the home.

Identification is also important because some kinds of insects are more damaging than others. Once you know what kind of insect is present, you can better judge whether or not the potential damage justifies control measures. Knowing the identity of a pest also helps you learn about the insect's biology, enabling you to use other IPM tools to control the insect.

Pest population size. Knowing the number of pests present will help you estimate their impact and whether there is sufficient cause to spend time and money on control. Different numbers of pests may be damaging in different situations. For instance:

— One cockroach in a home is usually sufficient cause to start some kind of control measure, but a few in an outbuilding will probably not invade the home and would not need to be controlled.

— A small number of white grubs in a vegetable garden may cause heavy damage to root crops such as potatoes, carrots, and onions, but cause no yield loss to nonroot crops such as tomatoes, beans, and cabbage.

IPM Tools

Various control measures may be used on a pest population. Individual IPM tools may be more or less successful, depending on the situation and the biology of the pest. A good IPM program will usually combine two or more of these tools to control the pest.

Mechanical control. The use of mechanical devices to keep out or kill pests. These methods are frequently too labor intensive to be profitable commercially. However, in the relatively small areas of home landscapes, garden plots, and houses, mechanical devices may be very useful.

— Handpicking: removing insect pests by hand. Useful in controlling Colorado potato beetle adults and larvae, tomato hornworms, eastern tent caterpillars, fall webworms, and bagworm eggs.

— Barriers: keeping pests from reaching an area where damage can be caused. Tin cans and other barriers around young tomato plants can be used to keep out cutworms. Screening windows can keep out flies and other winged pests.

— Devices: using mechanical devices to control insects. For example, flyswatters to kill flies or other home-invading pests and red sticky balls to capture apple maggots.

Ultrasonic devices have not been shown to be effective in repelling insect pests.

Biological control. The use of other living organisms to control a pest. Naturally occurring predators, parasites, and diseases are very effective in reducing pest populations. When we increase the numbers of these natural enemies, we are practicing biological control.

— Augment the habitat to increase favorable conditions for the natural enemy so that it can become more numerous. Allow fallen leaves and other debris to accumulate in such areas as the base of shrubs to provide overwintering sites for lady beetles and other predatory insects. Leave vegetation that harbors mite predators beneath fruit trees to help control mite pests on the trees.

— Introduce more natural enemies into the area. For example, spray *Bacillus thuringiensis kurstaki* to control cabbage looper, imported cabbage worm, eastern tent caterpillar, and cankerworms; introduce minnows or other fish into ornamental pools to control mosquitos.

Cultural control. Controlling pests by changing the methods used to grow or maintain the plants, animals, or buildings that are attacked.

— Planting time: Early plantings of sweet corn will reduce damage by corn earworm. Planting zucchini squash early will allow more of the crop to be harvested before damage by squash vine borer occurs.

— Habitat changes: Good sanitation in the home will reduce cockroach numbers. Proper fertilization and growing conditions for shade trees help prevent borer infestations.

Chemical control. The use of chemical insecticides is an integral part of many IPM programs. Pesticides are commonly used for economical control of the pest population. Properly timed insecticide applications frequently provide adequate control so that additional applications are not necessary.

Resistant varieties. Pest problems can be avoided or lessened by growing plant varieties or raising animals that are not heavily attacked by the pest in question.

— Plant birch varieties such as whitespire or heritage that are resistant to bronze birch borer.

— Butternut squash is more resistant to squash vine borer than are acorn or blue hubbard squashes. Zucchini squash appears to be the most susceptible summer squash variety.

Prevention. Pest problems can be avoided by keeping an insect pest out of the area where the crop is being grown. This is normally accomplished by governmental agencies with the assistance and cooperation of the public.

— Efforts made in keeping gypsy moth out of Illinois.

— Efforts made in keeping Mediterranean fruit flies and Africanized honey bees out of the U.S.A.

Another form of pest prevention is simply avoiding the food plants of particular pests. Careful selection of landscape or garden plants can prevent pest problems that might otherwise be difficult to control.

NAMES OF INSECTICIDES

Below is a list of the common names of insecticides used in the tables, followed by the commercial trade name and the chemical name. Some products may be available under a variety of trade names not listed below. Be sure to read the label. The label on the container always lists these products by the common name or chemical name.

Common name	Trade name	Chemical name
acephate	Orthene	O, S-dimethyl acetylphosphoramidothioate
Bacillus thuringiensis	Dipel, Thuricide, SOK-BT, Caterpillar Attack	
Bacillus thuringiensis 'israelensis'	Mosquito Attack	
Bacillus thuringiensis 'san diego'	M-One	
carbaryl	Sevin	1-naphthyl methylcarbamate
chlorpyrifos	Dursban	O, O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate
DEET	Off, Cutter's	N, N-diethyl-m-toluamide
diazinon	Spectracide	O, O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate
dicofol	Kelthane	1,1-Bis(chlorophenyl)-2,2,2-trichloroethanol
dimethoate	Cygon	O, O-dimethyl S-(N-methyl carbamoyl methyl) phosphorodithioate
hydrazone	Combat	Tetrahydro-5,5-dimethyl-2(IH)-pyrimidinone (3-[4-(trifluoromethyl)phenyl]-1-(2-[4-trifluoromethyl)phenyl]-ethenyl)-2-propenylidene)hydrazone
hydroprene	Gencor	Ethyl-3,7,11-trimethyl dodeca-2,4 dienoate
malathion	Cythion	diethyl mercaptosuccinate, S-ester with O, O-dimethyl phosphorothioate
methoprene	Precor, Pharorid	Isopropyl-11-methoxy-3,7,11 trimethyl-2,4 dodecadienoate
naled	Dibrom	1,2-Dibromo-2,2-dichloroethyl dimethyl phosphate
propoxur	Baygon	2-(1-methylethoxy) phenyl methylcarbamate
pyrethroids		
d-trans allethrin		allyl homolog of cinerin I
d-phenothrin	Sumithrin	3-phenoxybenzyl d-cis & trans 2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate
pyrethrin	Pyrenone	principally from plant species *Chrysanthemum cinariaefolium*
resmethrin	Chryson, SBP-1382	(5-benzyl-3-furyl) methyl 2,2 dimethyl-3-(2-methylprophenyl) cyclopropanecarboxylate
tetramethrin	Neo-Pynamin, Phthalthrin	(1-cyclohexene-1,2-dicarboximido)-methyl 2,2-dimethyl-3-(2-methylpropenyl)-cyclopropanecarboxylate
tetrachlorvinphos	Rabon	2-chloro-1-(2,4,5,-trichlorophenyl) vinyl dimethyl phosphate

CONVERSION TABLE FOR SMALL QUANTITIES

1 level tablespoon = 3 level teaspoons	1 pint = 2 cups
1 fluid ounce = 2 tablespoons	1 quart = 2 pints or 32 fluid ounces
1 cup = 8 fluid ounces or 16 tablespoons	1 gallon = 4 quarts or 128 fluid ounces

VEGETABLE INSECTS

Insects	Crop	Insecticide	Suggestions
Aphids (NHE-47) Mites (NHE-58) Thrips	Most garden crops	malathion insecticidal soap	Apply on foliage to control the insects. Aphids and leafhoppers transmit plant diseases; early control is important. Mites web on the underside of leaves; apply insecticide to underside of leaves early before extensive webbing occurs.
Blister beetles (NHE-72) Cutworms (NHE-77) Flea beetles (NHE-36) Grasshoppers (NHE-74) Leafhoppers (NHE-22) Picnic beetles (NHE-40)	Most garden crops	carbaryl rotenone	For cutworms, attach collars of paper, aluminum foil, or metal at planting for small numbers of plants, or apply insecticide to base of plants at first sign of cutting. Control grasshoppers in garden borders when hoppers are small. For picnic beetles, pick and destroy overripe or damaged vegetables.
All cabbage worms (NHE-45)	Cabbage and related crops, salad crops, and leafy vegetables	*Bacillus thuringiensis*[1]	Presence of white butterflies signals start of infestation. Control worms when small. It is almost impossible to raise cole crops in Illinois without controlling these pests.
Hornworms (NHE-130) Fruitworms	Tomatoes	carbaryl *Bacillus thuringiensis*[1]	Handpicking usually provides satisfactory control of hornworms.
Earworms (NHE-33)	Tomatoes and sweet corn	carbaryl	Apply to late-maturing tomatoes 3 to 4 times at 5- to 10-day intervals from small-fruit stage. Apply at fresh-silk stage to early and late corn every 2 days 4 to 5 times.
Colorado potato beetles	Eggplant, potatoes, tomatoes	carbaryl rotenone *Bacillus thuringiensis* 'san diego'	Apply as needed. Insects usually present only in late May and June. Handpick larvae and adults off of plants.
Potato leafhoppers (NHE-22)	Potatoes, beans	carbaryl or malathion	Apply 3 to 4 times at weekly intervals starting in late May or early June. Late potatoes and beans require additional treatments. Most serious pest of potatoes and beans in Illinois.
Bean leaf beetles (NHE-67)	Beans	carbaryl rotenone	Leaves are riddled in early plantings. Apply once or twice as needed.
Mexican bean beetles	Beans	carbaryl rotenone	Except for southern Illinois, only a pest of late beans. Apply insecticide to underside of leaves.
Cucumber beetles (NHE-46)	Vine crops	carbaryl rotenone	Apply as soon as beetles appear in spring. When blossoming begins, apply insecticide late in the day so as not to interfere with pollination by bees. Cover plants with polyester row covers until blooming starts to protect plants without insecticides in the spring.
Squash vine borers (NHE-8)	Squash	carbaryl	Make weekly applications to crowns and runners when plants begin to vine. Apply late in day. Cover plants with polyester row covers until blooming starts to protect plants without insecticides in the spring.
Corn borers	Sweet corn	carbaryl	Apply 4 times every 3 days to whorl and ear zone of early corn when feeding appears on whorl leaves.
Soil insects (including grubs, wireworms, root maggots)	All crops	diazinon	Mix 6 fluid ounces of 25% diazinon emulsion in enough water to cover 1,000 sq. ft., usually 2 to 3 gallons. Rake into soil. Cover the soil with screening along rows of root maggot susceptible plants in the spring.

Days Between Application and Harvest

	Collards, kale, and other leafy crops	Beans	Lettuce	Cabbage and related crops	Sweet corn	Onions	Vine crops[2]	Tomatoes	Pumpkin	Eggplant	Peas	Potatoes
carbaryl	14	0	14	3	0	..	0	0	0	0	0	0
malathion	7	1	14	7	5	3	1	1	3	3	3	0
rotenone	1	1	1	1	1	..	1	1	..	1	1	1

Amount of Insecticide for Volume of Spray for Vegetable Insects

	1 gal.	6 gal.	100 gal.	Commercial dust
carbaryl 50% W.P.	2 tbl.	¾ cup	2 lb.	5%
malathion 50-57% E.C.	2 tsp.	4 tbl.	1 qt.	4%
rotenone 1% W.P.	6-8 tbl.	2¼-3 cups	6-8 lb.	1%

E.C. = emulsion concentrate; W.P. = wettable powder. An emulsion concentrate is a chemical pesticide dissolved in a solvent to which an emulsifier has been added. It can then be mixed with water to the desired strength before being used.

[1] No time limitations. Sold as Dipel, Thuricide, SOK-BT, and others. [2] Apply insecticides late in the day after blossoms have closed to avoid bee kill.

FLOWER INSECTS

Insect	Insecticide[1]	Dosage	Suggestions
Ants, soil-nesting wasps, and sowbugs (NHE-79, 93, 111) White grubs	diazinon 25% E.C.	1 cup per 1,000 sq. ft.	Drench into soil.
Aphids, mealybugs, spittlebugs, lacebugs, scales (NHE-7, 114)	malathion 50-57% E.C. acephate 15.6% E.C. insecticidal soap	2 tsp. per gal. water 4 tsp. per gal. water follow label directions	Spray foliage thoroughly. Repeat treatments may be needed.
Blister beetles (NHE-72)	carbaryl 50% W.P.	2 tbl. per gal. water	Spray foliage. Repeat treatments may be needed.
Cutworms (NHE-77)	diazinon 25% E.C. diazinon 5% granules	6 oz. per 2-3 gal. water 2½ lb. per 1,000 sq. ft.	Spray 1,000 sq. ft. soil at base of plants. Do not spray on plant foliage. Small numbers of plants can be protected with collars of paper, aluminum foil, or metal.
Earwigs (NHE-142)	carbaryl 50% W.P.	2 tbl. per gal. water	Spray foliage as needed. Do not spray blooms.
Grasshoppers (NHE-74)	carbaryl 50% W.P. malathion 50-57% E.C.	2 tbl. per gal. water 2 tsp. per gal. water	Spray foliage and also adjacent grassy or weedy areas.
Iris borer	dimethoate (Cygon 2E)	4 tsp. per gal. water	Apply when irises are in bloom, but not on blooms and make only one application. Add a small amount of liquid detergent to spray mix to improve coverage on leaves.
Leaf-feeding beetles Leaf-feeding caterpillars Plant bugs and leafhoppers	carbaryl 50% W.P. acephate 15.6% E.C.	2 tbl. per gal. water 4 tbl. per gal. water	Spray foliage. Repeat treatments if needed.
Slugs (NHE-84)	metaldehyde bait Mesurol 2% bait		Apply as a bait to soil. Remove old leaves, stalks, poles, boards, and other debris where slugs like to hide and lay eggs. Shallow dishes of stale beer sunk into the ground will attract and kill many slugs.
Springtails (NHE-70)	malathion 50-57% E.C. malathion 4% dust	2 tsp. per gal. water	Spray foliage and soil. Apply to base of plants.
Stalk borers (NHE-24)	Same as for leaf-feeding beetles		Spray foliage thoroughly and frequently.
Thrips	Same as for leaf-feeding beetles		Spray foliage carefully.
White flies (NHE-136)	pyrethrin 0.1% resmethrin insecticidal soap	aerosol spray follow label directions	Spray foliage thoroughly. Repeat in 5 days.

E.C. = emulsion concentrate; W.P. = wettable powder.

[1] Use only one insecticide from those listed. Do not use oil-base sprays on plants. Do not use malathion on African violets. Do not use carbaryl on Boston ivy. Do not use diazinon on ferns. Repeated use of carbaryl foliage sprays may cause mite or aphid infestations to increase and to become damaging. Do not use insecticides during full bloom. Do not use dimethoate on chrysanthemums.

TREE AND SHRUB INSECTS

Insects	Insecticide[1]	Suggestions[2]
Aphids (NHE-7)	acephate diazinon malathion insecticidal soap	Spray foliage thoroughly with force when aphids become numerous. Repeat as needed. Check for presence of lady beetles and other predators before spraying.
Bagworms (NHE-6)	acephate carbaryl malathion *Bacillus thuringiensis*[3]	Spray foliage thoroughly. Apply June 15. Later sprays are less effective. For late spraying, use *Bacillus thuringiensis.* Handpicking of bags in winter and early spring will reduce later infestations.
Borers Bronze birch (NHE-143)	dimethoate	Spray trunk and limbs thoroughly in late May and early June. Repeat in 3 weeks or apply 6-inch band of concentrate to trunk. Keep trees watered if dry during the summer. Keep trees healthy and vigorous.
Flatheaded apple tree Oak	chlorpyrifos	Spray trunk and/or limbs in mid-May and repeat 4 weeks later. Keep trees healthy and vigorous and avoid trunk wounds.
Ash (NHE-145) Lilac (NHE-145) Peach tree	chlorpyrifos	Spray trunk and limbs in mid-June and repeat 4 weeks later. Keep the tree healthy and vigorous and avoid wounds or injury to the trunk. Prune out large lilac trunks.
Cankerworms (NHE-95)	acephate carbaryl malathion *Bacillus thuringiensis*[3]	Spray foliage when feeding or worms are first noticed in spring.
Eastern tent caterpillars	Same as for cankerworms	Spray when nests are first noticed. Remove nests and destroy.
Elm leaf beetles (NHE-82)	acephate *Bacillus thuringiensis* 'san diego' carbaryl	Spray as soon as damage is noticed.
European pine shoot moths and Nantucket pine moths (NHE-83)	dimethoate	Spray ends of branches thoroughly in late June for European species and in mid-May for Nantucket species.
Fall webworms	acephate carbaryl malathion *Bacillus thuringiensis*[3]	Spray when first webs appear; clip off and destroy infested branches or burn out webs.
Galls (NHE-80, 81) Elm cockscomb Hickory Maple bladder	diazinon malathion	Spray foliage thoroughly when buds are unfolding. Sprays after galls form on leaves are ineffective. Galls rarely harm the tree.
Hackberry blister	acephate diazinon malathion	Spray foliage thoroughly in late May. Kills psyllids in galls. Sprays after galls form on leaves are ineffective. Galls are not harmful to the tree.
Cooley spruce Eastern spruce	diazinon malathion	Apply in late September or October or early spring just after bud break.
Green-striped mapleworms	Same as for cankerworms	Spray as soon as damage is noticed.
Leaf miners Boxwood Hawthorn Oak	diazinon malathion acephate	Spray foliage thoroughly when miners first appear. Repeat treatment in 10 to 12 days. Use acephate only on oak. Leaf miners usually do not harm the tree.
Birch Holly	dimethoate	Repeat treatment in 3 weeks.
Mealybugs	acephate malathion insecticidal soap	Spray foliage thoroughly and with force. Repeat in 2 weeks.
Mimosa webworms (NHE-109)	acephate malathion *Bacillus thuringiensis*[3]	Spray foliage thoroughly when first nests appear (June, July). A repeat treatment for second-generation larval feeding may be needed (August).
Oak kermes	malathion	Spray foliage thoroughly about July 1 to kill the crawlers.
Periodical cicadas (NHE-113)	carbaryl	Spray all branches thoroughly when adults appear. Repeat in 7 to 10 days. Protect very young trees (<2″ dia.) with screening around the top and trunk.
Sawflies	carbaryl	Spray as soon as worms or damage is evident. Handpicking is also effective.
Scales (NHE-100, 114, 146)	diazinon malathion acephate	Spray foliage thoroughly in early April for *Fletcher* and *European elm scale;* in late May for *pine needle* and *sweet gum scale;* in early June for *scurfy, oystershell,* and *euonymous scales;* in early July for *cottony maple, Juniper,* and *dogwood scales;* in mid-July for *spruce bud scale;* and again in August for *oystershell scale.*

[1] Use only one insecticide of those listed. [2] Treatment dates listed are for central Illinois. In southern Illinois, apply 2 weeks earlier; in northern Illinois, 2 weeks later. [3] Trade names: Dipel, Thuricide, SOK-BT, and others.

TREE AND SHRUB INSECTS (continued)

Insects	Insecticide[1]	Suggestions[2]
Cottony maple (NHE-144), Putnam, San Jose, Tulip tree	dormant oil diluted according to label	Apply when plants are still dormant in late winter. Do not use on evergreens. For tulip tree scale, a malathion spray in late September or in early spring is also effective.
Sycamore lace bugs Plant bugs	acephate carbaryl malathion	Spray when nymphs appear, usually in late May.
Thrips	Same as for aphids	Mainly on privet. Spray foliage thoroughly.
Yellow-necked caterpillars	acephate carbaryl malathion *Bacillus thuringiensis*	Spray foliage when worms are small (July).
Zimmerman pine moths (NHE-83)	chlorpyriphos dimethoate	Spray trunk and branches in mid-April for young larvae and/or mid-August for adults and young larvae.

[1] Use only one insecticide from those listed. [2] Treatment dates listed are for central Illinois. In southern Illinois, apply 2 weeks earlier; in northern Illinois, 2 weeks later. [3] Trade names: Dipel, Thuricide, SOK-BT, and others.

Amount of Insecticide Needed for Volume of Spray for Tree and Shrub Insects

	1 gal.	6 gal.	100 gal.		1 gal.	6 gal.	100 gal.
acephate (Orthene) 15.6% E.C.[1]	4 tsp.	1 cup	2 qt.	diazinon 25% E.C.[4]	2 tsp.	4 tbl.	1 qt.
carbaryl (Sevin) 50% W.P.[2]	2 tbl.	¾ cup	2 lb.	dimethoate (Cygon 2E)[3]	2 tsp.	4 tbl.	1 qt.
chlorpyrifos (Dursban 2E)	2 tsp.	4 tbl.	1 qt.	malathion 50-57% E.C.[5]	2 tsp.	4 tbl.	1 qt.

E or E.C. = emulsion concentrate; W.P. = wettable powder.

[1] Do not use on flowering crab, sugar maple, redbud, American elm, Lombardy poplar, or cottonwood. [2] Do not use on Boston ivy. [3] Do not use on chrysanthemums. [4] Do not use on ferns or hibiscus. [5] Do not use on canaert red cedar.

LAWN INSECTS

Insects	Insecticide[1]	Dosage per 1,000 sq. ft.[2]	Suggestions
White grubs (NHE-104, 147)	diazinon 25% E.C. 5% G.	1 cup 2½ lb.	Apply as spray or granules to small area and then water in thoroughly before treating another small area. Grub damage will usually occur in late August and in September.
Ants (NHE-111) Cicada killer and other soil-nesting wasps (NHE-79, 150)	diazinon 25% E.C. 5% G. chlorpyrifos 5 or 6% E.C.	¾ cup 2 lb. 1 cup	Apply as spray or granules and water in thoroughly. For individual nests pour 1% diazinon in nest and cover with soil.
Sod webworms (NHE-115)	carbaryl 50% W.P. diazinon 25% E.C. 5% G. chlorpyrifos 5 or 6% E.C.	½ lb. ¾ cup 2 lb. 8 fl. oz. (1 cup)	As sprays, use at least 2.5 gal. of water per 1,000 sq. ft. Do not water for 72 hours after treatment. As granules, apply from fertilizer spreader. Webworms usually damage lawns in late July and in August.
Millipedes and sowbugs (NHE-93)	carbaryl 50% W.P. diazinon 25% E.C. chlorpyrifos 5 or 6% E.C.	½ lb. ¾ cup 1 cup	Spray around home where millipedes or sowbugs are crawling. If numerous, treat entire lawn.
Armyworms Cutworms	carbaryl 50% W.P. chlorpyrifos 5 or 6% E.C.	2 oz. 1 cup	Apply as sprays or granules. Use 5 to 10 gal. of water per 1,000 sq. ft.
Chinch bugs	chlorpyrifos 5 or 6% E.C. diazinon 25% E.C. 5% G.	1 cup ¾ cup 2 lb.	Spray infested areas where chinch bugs are present.
Aphids (NHE-148)	acephate 15.6% E.C.	4½ fl. oz.	Spray grass thoroughly.
Slugs (NHE-84)	Mesurol 2% bait		Apply where slugs are numerous. Scatter in grass. For use only in flower gardens and shrubbery beds.
Bluegrass billbugs	chlorpyrifos 5 or 6% E.C.	1 to 2 cups	Apply as a spray in spring to lawn damaged in previous year. Drench at high rate in July if damage is observed.

E.C. = emulsion concentrate; W.P. = wettable powder; G. = granules.

[1] Use only one insecticide from those listed. [2] To determine lawn size in square feet, multiply length times width of lawn and subtract non-lawn areas including house, driveway, garden, etc. Do not allow people or pets on the lawn until the spray has dried.

HOUSEHOLD INSECTS

Insects	Insecticide[1]	Suggestions for control
Ants (NHE-111) Carpenter ants (NHE-10)	*Outdoors:* diazinon 25% E.C. *Indoors:* chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U. hydrazone baits propoxur baits boric acid R.T.U.	**Chemical.** Use diazinon to spray completely around outside foundation and the adjacent 1 ft. of soil. Apply an R.T.U. spray to baseboards, cracks, and door thresholds. Apply boric acid in out-of-reach areas only. **Nonchemical.** Keep foods in tightly sealed containers or in the refrigerator. Most ants prefer sweets and fats. Practice good sanitation. Avoid leaving dirty dishes or other food particles where they are accessible to ants. Caulk cracks and crevices in house foundation.
Ants, Pharaoh	methoprene baits boric acid baits	**Chemical.** *Indoors:* Place baits near ant food and water sources and in other areas where ants are found. Treat for several weeks, replacing bait as it becomes dry. **Nonchemical.** Follow suggestions above for other ants. Apply petroleum jelly or double-sided tape to furniture legs to keep ants off of furniture.
Boxelder bugs (NHE-9)	diazinon 25% E.C. carbaryl 50% W.P. insecticidal soap	**Chemical.** Spray boxelder bugs on tree trunks, foundation walls (diazinon and insecticidal soap), under eaves, and other areas where they gather. Use carbaryl on foliage where beetles are feeding. **Nonchemical.** Keep screens, and other openings in good repair. Caulk all seams around windows and doors. Indoors remove the bugs by vacuuming.
Carpet beetles, clothes moths (NHE-87)	chlorpyrifos R.T.U. diazinon R.T.U.	**Chemical.** Spray storage areas, edges of carpeting, baseboards, cracks and crevices. **Nonchemical.** Destroy all badly infested materials. If insulation is of plant or animal origin remove it from the structure. Check for any dead animal or bird carcasses that may be in wall voids, chimneys, or fireplace areas. Keep accumulation of lint to a minimum and vacuum thoroughly in areas where hair and other natural fibers gather. Remove all bird, insect, and rodent nests in the fall before cool weather. Place cleaned or washed woolens in insect-free chests that are tightly sealed or in plastic bags. Dry cleaning and laundering kills these pests.
Carpenter bees	carbaryl 5% dust diazinon R.T.U.	**Chemical.** Dust and spray entrances to nest with insecticide. Do not plug entrance. **Nonchemical.** In the fall, fill the holes and paint or varnish the entire wood surface.
Centipedes, millipedes, sowbugs (NHE-93)	*Outdoors:* diazinon 25% E.C. *Indoors:* chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U.	**Chemical.** Apply diazinon as an outside foundation spray. If millipedes are abundant, treat entire lawn according to label. *Indoors:* Use R.T.U. spray according to label. **Nonchemical.** Correct situations where moist habitats occur such as crawl spaces, poorly drained areas, and piles of trash, mulch, or compost. Remove indoors by vacuuming.
Chiggers (NHE-127)	diazinon 25% E.C. DEET R.T.U.	**Chemical.** Treat lawns, roadsides, and areas not mowed. For personal protection, a repellent such as DEET will prevent attack. **Nonchemical.** Eliminate or mow breeding sites, especially briars, weeds, and other thick vegetation where there is an abundance of moisture and shade. Wear protective clothing such as a long-sleeved shirt and trousers, shoes, and socks. Tuck pant legs into boots or socks. Avoid sitting on the ground either in the lawn or brushy areas. Take a warm soapy shower or bath immediately after returning from any infested areas.
Clover mites (NHE-2)	pyrethroid R.T.U. dicofol 35% W.P.	**Chemical.** Apply dicofol spray to outside foundation and adjacent 1 ft. of soil. *Indoors:* Spray with pyrethroid. **Nonchemical.** Eliminate grass and other vegetation in a 1 ft. band all the way around the house. Also make sure window and door seams are properly caulked and sealed to prevent entry by the mites. *Indoors:* Mites can be removed by vacuuming.

E.C. = emulsion concentrate; W.P. = wettable powder; R.T.U. = ready to use; G. = granules.

[1] Whenever possible, purchase specially prepared, ready-to-use forms of insecticides for indoor use. Use only one insecticide from those listed. When preparing a quantity of 1 gallon or more of a spray, follow the mixing directions on the pesticide label.

Insects	Insecticide[1]	Suggestions for control
Cluster flies (NHE-1)	pyrethroid R.T.U.	**Chemical.** Fog lightly in rooms with pyrethroid. Repeat spray as needed. **Nonchemical.** Seal cracks and openings around windows, eaves and siding. Use fly screen over air intake vents or air conditioning systems. Seal off attic openings with screen or caulking. *Indoors:* Remove flies by vacuuming.
Cockroaches German (NHE-3) Brown-banded (NHE-4) American and Oriental (NHE-5)	chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U. boric acid R.T.U. hydroprene R.T.U. hydrazone bait propoxur bait	**Chemical.** Spray roach runways and hiding places. Treat under sink, refrigerator, cabinets, on baseboards, etc. Treatment throughout home may be needed to control brown-banded roaches. May be supplemented with boric acid applied into out-of-sight and out-of-reach voids under cabinets and appliances. **Nonchemical.** Practice proper sanitation by keeping food properly sealed or stored in the refrigerator. Keep trash covered. Do not allow dirty dishes to accumulate. Clean frequently under refrigerators and stoves where food particles may accumulate. Eliminate hiding places such as piles of newspapers, boxes and papers. Caulk cracks and crevices. Do not leave pet food out overnight.
Crickets (NHE-137) Field House Camel	*Outdoors:* diazinon 25% E.C. *Indoors:* chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U. propoxur bait	**Chemical.** Use diazinon to spray completely around outside foundation and the adjacent 1 ft. of soil. Apply an R.T.U. spray to baseboards, cracks, and door thresholds. **Nonchemical.** Cracks and crevices around windows, doors, and in the foundation should be properly sealed and caulked. *Indoors:* Remove crickets by vacuuming. House lights attract both field and house crickets. Keep garbage cans clean and empty frequently. Keep firewood at least 1-2 feet away from the foundation. Apply a 6-inch band of ashes around the wood pile. Eliminate sources of moisture by fixing leaky pipes and modifying damp areas.
Drain flies (NHE-91)	pyrethroid R.T.U.	**Chemical.** Use chemicals only after solving sanitation problems. Pour boiling water or rubbing alcohol into overflow drain to eliminate maggots. **Nonchemical.** Practice proper sanitation. Clean out overflow drains, drain traps, and basement drains. Keep screens in good repair.
Earwigs (NHE-142)	*Outdoors:* diazinon 25% E.C. *Indoors:* chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U. propoxur bait	**Chemical.** Apply diazinon as an outside foundation spray. *Indoors:* Use R.T.U. spray according to label. **Nonchemical.** Remove unessential plant debris, mulch, and boards from around buildings. Establish a zone of bare concrete or soil which will dry out. *Indoors:* Remove by vacuuming. Caulk cracks and crevices around windows, doors, and in the foundation.
Elm leaf beetles (NHE-82)	carbaryl 50% W.P. *Bacillus thuringiensis* 'san diego'	**Chemical.** Spray nearby Chinese elm trees during the summer to reduce the number of beetles that come into homes in the fall. **Nonchemical.** Seal cracks and crevices around windows and other openings to prevent entry. *Indoors:* Remove by vacuuming.
Fleas (NHE-107)	naled	**Chemical.** Replace flea collars on pets about every 3 months. Some pets are allergic.
	carbaryl 5% dust	Dust pets directly as needed. Dust areas inside and outside the home where pets rest.
	methoprene R.T.U. pyrethroid R.T.U.	For infestations in the home, spray edges of carpets and rugs, and floors where fleas are observed. Follow label directions. Vacuum rugs and upholstered furniture thoroughly approximately 30 minutes after spraying.

E.C. = emulsion concentrate; W.P. = wettable powder; R.T.U. = ready to use; G. = granules.

[1] Whenever possible, purchase specially prepared, ready-to-use forms of insecticides for indoor use. Use only one insecticide from those listed. When preparing a quantity of 1 gallon or more of a spray, follow the mixing directions on the pesticide label.

HOUSEHOLD INSECTS (continued)

Insects	Insecticide[1]	Suggestions for control
Fleas (cont.)	diazinon 25%E.C.	**Chemical.** Apply to lawn. **Nonchemical.** Frequently launder pet bedding and rugs where pets frequent with hot soapy water. Vacuum thoroughly to remove lint and dust around baseboards and cracks where flea eggs and larvae accumulate. Eliminate vegetation that will serve as a harborage for the native mammal population (carriers of fleas). Prevent pets from resting under the house and exclude mammals by screening attic and eave entrances. Thoroughly clean furniture in areas pets tend to frequent.
Flies (NHE-16) Houseflies Gnats, Midges	*Outdoors:* malathion 50-57% E.C. *Indoors:* pyrethroid R.T.U.	**Chemical.** Use malathion to spray around garbage cans and other resting sites. Apply fine mist or fog of pyrethroid. **Nonchemical.** Proper sanitation is important. Dispose of refuse frequently and prevent the accumulation of rotting or decaying vegetation. Keep screens in good repair. Fly strips and fly swatters can also be effective.
Honey bees (NHE-141)	carbaryl 5% dust diazinon R.T.U. pyrethroid R.T.U.	**Chemical.** Drill holes through siding to inject insecticide, if necessary. Remove nests and honey and destroy them. Treat nests at dusk or dawn. **Nonchemical.** Caulk cracks and crevices during the winter or early spring to prevent nest building. Seal off attic openings, air intake vents, and air conditioning systems with fly screen.
Lice (NHE-105) Human Head Crab Body	Kwell 1% shampoo pyrethrin R.T.U.	**Chemical.** Dust lightly over body hair. Repeat in 2 weeks if needed. Do not get in eyes. Consult a physician. **Nonchemical.** Practice proper personal hygiene. Avoid using other individuals' combs, hats, towels, or hair brushes. Bedding and clothing should be changed and washed frequently. Sanitation of locker rooms, and proper laundering will help reduce the incidence of lice. Crab louse is usually transmitted through intimate sexual contact.
Mites, Human Human scabies Human itch mite (NHE-135)	Kwell 1% lotion available only by a physician's prescription pyrethrin R.T.U.	**Chemical.** Consult a physician. **Nonchemical.** Consult a physician.
Mosquitoes (NHE-94,132)	*Outdoors:* malathion 50-57% E.C. pyrethroid fogger *Bacillus thuringiensis* 'israelensis' *Indoors:* pyrethroid R.T.U.	**Chemical.** Spray tall grass, around doorways, and other resting sites. Use a repellent like DEET when entering mosquito-infested areas. Apply fine mist or fog of pyrethroid. **Nonchemical.** Keep screens in good repair. Flues and chimneys should be covered during the summer months. Eliminate resting places such as tall grass, weeds, shrubbery, and vines from around the home. Eliminate rain-water-collecting items such as old tires, pans, cans, and buckets. Weekly, drain plastic swimming pools and bird baths. Provide for proper water drainage around the foundation of the home. When visiting mosquito-infested areas, wear protective clothing to prevent bites. If small garden ponds are present use Top minnows *Gambusia* sp. or *Bacillus thuringiensis* 'israelensis'. *"Bug zappers" and ultrasonic devices have not proven to be extremely effective in controlling mosquitoes and other noxious flying insects.*
Pantry and Cereal Pests (NHE-11) Grain beetles Indian meal moth Flour beetles	diazinon R.T.U. propoxur R.T.U. chlorpyrifos R.T.U. pyrethroid R.T.U.	**Chemical.** Force spray into cracks and crevices; allow to dry; cover shelves with clean, fresh paper. Do not contaminate food or utensils with insecticide. **Nonchemical.** Discard infested packages. Thoroughly clean and vacuum food cabinets and shelves. Keep dry food in tightly sealed containers. Keeping nonhuman food at 32°F for 3-4 days will kill eggs and larvae.
Powder-post beetles (NHE-85)	chlorpyrifos 42% E.C.	**Chemical.** Use chlorpyrifos to paint or spray infested unfinished wood. Follow label directions. **Nonchemical.** Avoid buying furniture or wood products that have not been stained, varnished or properly dried. Properly paint or varnish new wood items to seal pores and to prevent egg laying.

E.C. = emulsion concentrate; W.P. = wettable powder; R.T.U. = ready to use; G. = granules.

[1] Whenever possible, purchase specially prepared, ready-to-use forms of insecticides for indoor use. Use only one insecticide from those listed. When preparing a quantity of 1 gallon or more of a spray, follow the mixing directions on the pesticide label.

Insects	Insecticide[1]	Suggestions for control
Silverfish (NHE-86)	diazinon R.T.U. propoxur R.T.U. chlorpyrifos R.T.U. boric acid R.T.U.	**Chemical.** Spray runways, baseboards, closets, and places where pipes go through the walls. Repeat treatments in 2 weeks if needed. Apply boric acid in out-of-reach areas only. **Nonchemical.** Alter the physical environment of the infested area by reducing the humidity. Reduce harborage sites by caulking cracks and crevices. Eliminate their food source by storing books, papers, and linens in tightly sealed containers or cabinets.
Spiders (NHE-17, 116)	*Outdoors:* diazinon 25% E.C. *Indoors:* chlorpyrifos R.T.U. diazinon R.T.U. propoxur R.T.U.	**Chemical.** Use diazinon to spray completely around outside foundation and the adjacent 1 ft. of soil. Apply R.T.U. spray to baseboards, cracks, and door thresholds. *Do not use diazinon E.C. inside.* **Nonchemical.** Keep screens and other openings in good repair. Caulk all seams around windows and doors. Spiders are considered beneficial as they are predators of insects and other small animals. *Indoors:* Remove by simply vacuuming.
Springtails (NHE-70)	*Outdoors:* diazinon 25% E.C.	**Chemical.** *Outdoors:* Spray soil next to the house, especially grassy moist areas. **Nonchemical.** Eliminate moist areas around the home where mulch and rotting vegetation are present. Keep outside light use to a minimum. Keep screens and doors in good repair. Allow potting soil of houseplants to dry out between waterings.
Swimming pool insects (NHE-103)	Do *not* add insecticides to pool water	**Chemical.** None. **Nonchemical.** Keep outside light to a minimum. Maintain proper chlorine balance in the pool. Cover pool when not in use.
Termites (NHE-57)	chlorpyrifos 42% E.C. (Dursban T.C.) fenvalerate 24.5% E.C. (Tribute) permethrin (Dragnet 36.8% E.C.) (Torpedo 25.6% E.C.) cypermethrin 25.3% E.C. (Demon T.C.)	**Chemical.** Fenvalerate, cypermethrin, and permethrin are restricted-use pesticides. Control by pest control operator (exterminator) recommended. **Nonchemical.** Remove termite tubes connecting the soil to wood sources. Eliminate wood-to-soil contacts. Ventilate damp areas such as crawl spaces for proper drying. Use treated wood when landscaping or constructing outside structures. Cedar and redwood are somewhat resistant; termites prefer hardwoods.
Ticks (NHE-56) Brown dog tick American dog tick Deer tick Lone star tick	tetrachlorvinphos 50% W.P. malathion 50-57% E.C. carbaryl 50% W.P. carbaryl 5% dust tetrachlorvinphos 3% dust DEET R.T.U.	**Chemical.** Apply spray to lawns, fencerows, roadsides, and areas not regularly mowed. Dust pets directly as needed, according to label instructions. Dust baseboards, cracks, and crevices around pet bedding. Use a repellent like DEET when entering tick-infested areas. **Nonchemical.** Keep vegetation, weeds and brush, mowed and clean. Avoid areas where ticks are known to be present. Wear long-sleeved shirt and trousers when visiting infested areas, tuck pant-legs into socks. Check for ticks on skin or clothing every few hours. Vacuum baseboards and other cracks and crevices thoroughly to destroy eggs and immatures.
Wasps (NHE-141) Hornets Yellowjackets	carbaryl 5% dust diazinon R.T.U. pyrethroid R.T.U.	**Chemical.** For nests belowground, apply diazinon according to label and seal opening with soil. Spray aboveground wasp and hornet nests in partitions with carbaryl. Drill holes through siding to inject insecticide, if necessary. Remove nests and destroy them. Treat nests at dusk or dawn. **Nonchemical.** Keep garbage cleaned up and properly covered. Avoid indiscriminate killing of wasps, hornets, and yellowjackets, as they are considered beneficial. If picnicking, keep food properly covered or sealed. Avoid areas where yellowjackets are prevalent. Keep overripe fruit and vegetables cleaned up and away from human activity. Caulk cracks and crevices during the winter or early spring to prevent yellowjacket nests but do not caulk opening of active nest.

E.C. = emulsion concentrate; W.P. = wettable powder; R.T.U. = ready to use; G. = granules.

[1] Whenever possible, purchase specially prepared, ready-to-use forms of insecticides for indoor use. Use only one insecticide from those listed. When preparing a quantity of 1 gallon or more of a spray, follow the mixing directions on the pesticide label.

FOR YOUR PROTECTION

1. Store insecticides out of reach of children, irresponsible persons, or animals; store preferably in a locked cabinet.

2. If you use a bait around or in the home, place it after the children have retired and pick it up in the morning before they get up. Furthermore, place it out of their reach. At present we do not encourage the use of baits for insect control.

3. Avoid breathing insecticide sprays and dusts over an extended period. This is particularly true in enclosed areas such as crawl spaces, closets, basements, and attics.

4. Wash with soap and water exposed parts of body and clothes contaminated with insecticide.

5. Wear rubber gloves when handling insecticide concentrates.

6. Do not smoke while handling or using insecticides.

7. Leave unused insecticides in their original containers with the labels on them and in locked cabinets.

8. Triple-rinse empty pesticide containers. Wrap each container in several layers of paper. Dispose of the containers one at a time through the municipal solid-waste-disposal system.

9. Do not leave puddles of spray on impervious surfaces.

10. Do not apply insecticides to fish ponds.

11. Do not apply insecticides near dug wells or cisterns.

12. Observe all precautions listed by the manufacturer on the label.

1990 Insect Pest Management Guide

STORED GRAIN

Grains produced in Illinois may be stored for periods of a few weeks to a few years before feeding or processing. The profitability of such storage depends not only upon marketing concerns, but also upon maintenance of grain quality. It is important to remember that the harvest and storage of grain does not signal an end to the possibility of losses caused by insects and pathogens.

Successful management of stored-grain insects is possible only when proper storage practices are carried out. Insecticides and fumigants should be viewed as supplements to, not replacements for, sound storage methods. Used properly, however, insecticides and fumigants can help to limit insect losses in stored grains without endangering the pesticide applicator or resulting in excessive pesticide residues that threaten the health of consumers (livestock or humans) of treated grain or grain products.

This publication provides recommendations for cultural and chemical control of stored-grain insects. It is revised annually; always use the current year's issue. Registration changes that occur between revisions will be announced to appropriate media sources and county Extension offices.

USING INSECTICIDES AND FUMIGANTS

The U.S. Environmental Protection Agency has designated certain pesticides for "restricted" use. The grain fumigants aluminum phosphide, chloropicrin, and methyl bromide are restricted-use pesticides. *Commercial* applicators must be certified in order to apply restricted-use pesticides. Elevator employees responsible for grain treatment at their place of employment must be certified under the category "Grain Facility Pest Control Applicator." Commercial fumigation professionals who treat stored grain or grain products at farms, elevators, warehouses, etc. must be certified by the Illinois Department of Public Health. A *private* applicator who wishes to purchase or apply restricted-use pesticides "for the purpose of protecting any agricultural commodity on property owned or rented by him or as exchange labor (no compensation) on the property of another" must obtain certification by passing an examination administered by the Illinois Department of Agriculture. **Regulations recently enacted by the Illinois Department of Agriculture mandate that private applicators must obtain special certification to purchase and apply grain fumigants. To obtain certification for fumigant application, individuals must first pass the private applicator exam and then pass a grain storage and fumigation exam.**

Those who apply pesticides should be aware that the pesticide user is always responsible for the results of pesticide applications. To avoid accidents and maximize the effectiveness of any application, always read the pesticide label and follow all directions and safety precautions. Be sure that the pesticide is specifically labeled for the pest, site, and application method planned. **Remember: The label is the law.**

Poison Resource Centers. The Poison Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Resource Center will provide first-aid information and refer callers to local treatment centers if necessary.

Poison Resource Centers supplement, but do not replace, local emergency medical services. Do not delay calling local emergency medical personnel to request immediate assistance or transportation. If possible, have the pesticide container and label present when you call or reach a treatment center or hospital.

Chicago and northeast Illinois
1753 West Congress Parkway
Chicago, Illinois 60612
Telephone: 800-942-5969

Northern and central Illinois
530 N.E. Glen Oak
Peoria, Illinois 61603
Telephone: 800-322-5330

Central and southern Illinois
800 East Carpenter
Springfield, Illinois 62702
Telephone: 800-252-2022

A national pesticide telecommunications network can be reached by dialing 1-800-858-7378.

NOTE: The information that follows is provided for educational purposes only. Reference to commercial products or trade names does not constitute an endorsement

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
Prepared by Richard A. Weinzierl, Extension Entomologist CIRCULAR 1242-90 October 1989

ment by the University of Illinois and does not imply discrimination against similar products. Trade names are presented for reasons of clarity only. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

INSECTS ATTACKING STORED GRAIN

Several types of insects inhabit stored grain. Exact identification of these insects often is difficult because most stored-grain pests are extremely small (1/16 to 1/4 inch in length), and many separate species are very similar in appearance. Presenting identification information for the many species of stored-grain pests is not the purpose of this publication; materials containing such information are included in the reference listing at the end of this circular. It is important, however, to recognize the different groups of insects that live in stored grains because management considerations may differ according to the insects' characteristics.

Weevils and Other Insects that Feed Inside Kernels

The most damaging insect pests of stored grain are those that develop within grain kernels. These insects are referred to as internal pests or primary pests. Adults deposit eggs on or in whole kernels, and larvae develop hidden within kernels. Damage caused by internal pests makes grain more suitable for infestation by insects that feed externally on grain or grain debris.

The common primary pests of grains in Illinois are the weevils — rice weevil, maize weevil, and granary weevil. The grain weevils are small (between 1/16 and 1/8 inch in length), but recognizable as a group because the head bears a prolonged snout. Another primary pest found in wheat, but only rarely in corn, is the lesser grain borer. Recognition of this pest is possible because the adult lesser grain borer's head projects downward, not forward, from the anterior portion of the body. These insects may be found in any portion of the grain mass within a bin; they are not restricted to portions near the surface.

The larval stages of the Angoumois grain moth also feed within grain kernels. This insect can infest grain in the field; storage infestations are limited to near the surface of the grain mass.

Beetles that Develop and Feed Outside Grain Kernels

Most insects commonly collected in stored grain in Illinois are beetles that range in size from 1/16 inch to over 1/2 inch in length. Adults of most species are reddish brown to black in color, and their forewings are hardened to form a "shell" over the body. Larvae of common species are cylindrical and cream-colored; some bear fine hairs. Species frequently collected in Illinois grain bins include the sawtoothed grain beetle, flat grain beetle, rusty grain beetle, foreign grain beetle, hairy fungus beetle, larger black flour beetle, red flour beetle, and confused flour beetle.

Like the weevils, beetles that feed and develop outside grain kernels are not limited in distribution to the grain surface, but instead inhabit any portion of a grain mass. They feed on several different grains, but their buildup in any grain usually results from an abundance of broken kernels (fine material) or fungal growth on moist grain. Their dependence on fines or fungal growth accounts for the description of these insects as "secondary" pests, "bran bugs," or "fungus feeders." Concentrations of stored-product beetles cause an increase in grain moisture and temperature, and such changes favor continued population growth.

Surface-Feeding Caterpillars

Caterpillars that feed in stored grain inhabit primarily the outer portions of the grain mass (usually the grain surface, but also the bottom of the grain mass just above perforated drying floors or aeration ducts). These caterpillars reach approximately 3/4 inch in length and are cream-colored. They produce fine, silken webbing as they move about near the grain surface. Mature larvae pupate within a silky cocoon. Adult moths fly and mate in the bin headspace where they may be seen resting on the bin walls and roof.

The Indianmeal moth is the most common surface-feeding caterpillar in stored grain in Illinois. The adult Indianmeal moth has a wingspan of about 3/4 inch; the outer half of each front wing is reddish brown or copper-colored. Malathion resistance appears to be common in Illinois populations of Indianmeal moth. Other surface-feeding caterpillars include the Angoumois grain moth (which feeds within kernels), the Mediterranean flour moth, and the meal moth.

Other Stored-Grain Insects

Additional pests that sometimes infest stored grains include psocids (booklice) and grain mites. These soft-bodied pests feed on grain-rotting fungi. An abundance of psocids or grain mites often indicates a more important problem of mold-related deterioration of the grain.

Remember that not all insects in grain are pests. Parasitic wasps, larvae of a predaceous fly species, and predaceous Hemipterans (true bugs) attack certain grain pests. In addition, many field insects are inadvertently transported to grain bins where they cause no damage.

PREVENTION OF INSECT INFESTATIONS

Sources of Infestations

Some stored-grain insects can infest maturing grain crops in the field. Although some field infestations probably occur in Illinois, the extent of field-originated storage problems appears to be minor.

The most common sources of stored-grain insects are old grain, grain spills, feeds, seed, and grain debris. Insects often move to new grain from carry-over grain, from small amounts of grain not cleaned from "empty" bins, from feed supply buildings, and from grain debris beneath perforated floors of bins. Most pest species can fly at least short distances to reach new grain.

Sanitation

To minimize the migration of stored-product insects from current food sources to new grain, thorough cleanup practices are necessary. At least 2 weeks before storing new grain, clean all grain and grain debris from within and around grain bins. Be thorough; sweep or vacuum bin floors. Also remove and feed or destroy any grain and grain debris in combines, wagons, augers, etc. If grain debris is not removed from the combine, collect and feed or destroy the first few bushels of grain that pass through the combine.

Bin Sprays and Empty-Bin Fumigation

Insects may remain in certain bin locations even after a thorough cleanup is completed. Hard-to-clean sites that harbor insect pests include cracks and crevices in bin walls and the plenum beneath nonremovable perforated floors. Applying an insecticide or a fumigant in an empty bin can supplement (but not replace) physical cleanup efforts.

Apply an insecticide to the walls, ceiling, roof, and floor of all bins that will be used to store grain for more than a few weeks. Use:

- 4 fl oz malathion 57% EC in 2 gal water;

or

- 1 qt methoxychlor 25% EC in 2 gal water;

or

- 12 oz methoxychlor 50% WP in 2 gal water;

or

- 4 fl oz Reldan 4E (chlorpyrifos-methyl) in 3 gal water.

Spray all bin surfaces to the point of runoff, and be sure to thoroughly treat all cracks and crevices and around doors. Directing extra spray to and through perforated flooring will provide some control of insects living in grain debris in the subfloor plenum, but satisfactory control of insects in this space requires fumigation (or removal of the false floor to allow complete cleanup of debris in the plenum).

Fumigating empty bins to control insects in the subfloor plenum may be necessary if summer-harvested grain (wheat, etc.) is to be stored in the bin 1 month or longer or if fall-harvested crops (corn, soybeans, or grain sorghum) will be stored beyond May or June of the year following harvest. Empty bin fumigation is usually not necessary where grain will be treated with a protectant insecticide at the auger as it is binned. The fumigant chloropicrin (trade names are Chlor-o-pic, Larvacide 100, and Quasar) is labeled and effective for empty bin fumigation.

Chloropicrin is a restricted-use pesticide that is extremely toxic. The U.S. Environmental Protection Agency recently revised fumigant regulations to require the use of a canister respirator (gas mask) or self-contained breathing apparatus (SCBA) if applicators are exposed to chloropicrin. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific label directions concerning respiratory protection equipment and gas detection devices. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

Use chloropicrin only on relatively calm days when the outside air temperature is 65°F or higher. Before applying chloropicrin, use tape and polyethylene sheeting to seal the side door and all bin openings below the level of the side door. Be sure to seal fan openings and the unloading auger shaft. Post warning placards according to label directions. Always have a partner present when applying this or any other fumigant.

To fumigate the subfloor plenum of empty bins, pour in chloropicrin from a ventilation door on the bin roof. Wear a canister respirator equipped with a fresh canister when applying chloropicrin and climbing down from the bin roof. Use 1 quart per 250 square feet of floor area. Chloropicrin forms a pungent tear gas that settles in the lower portion of the bin. This gas will kill all stages of stored-grain insects beneath the subfloor, but chloropicrin will not spread to the upper portions of the bin to kill insects suspended in grain debris remaining on bin walls. Wait at least 24 hours before airing out the bin.

Filling the Bin

Effective insect management in stored grain starts with good grain storage practices. Use a grain cleaner to minimize the amount of fine material that is binned along with the grain. Many species of stored grain insects cannot survive in the absence of broken kernels and grain debris. Use of a grain spreader evenly distributes remaining fine material and helps to level the grain surface. Once the bin is full, if fine material is concentrated in a central core beneath the auger spout, removal of one or a few loads from the bin will extract this core of fines. Do not add new grain on top of old because insects will rapidly move from the infested grain to the new crop. Do not overfill bins; the levelled grain surface should be at least a few inches below the lip of the bin. Levelling the grain surface is important for uniform airflow and for effective insecticide or fumigant application.

Store only dry grain. Maintaining moisture levels that prevent the growth of storage fungi is sufficient where fall-harvested grain is to be stored only through the winter, but grains that will be stored 1 month or longer during warm, summer weather should be dried to 12-13 percent moisture. This moisture content is unfavorable for most grain insects; it also allows prolonged persistence of protectant insecticide residues.

Aerate to cool stored grain as soon as possible. Temperatures below 50°F prevent insect feeding and reproduction. Cooling grain to just above freezing will kill some stages of many grain insects. Aeration also results in uniform temperatures that prevent moisture migration problems within a bin. Most grain storage references recommend aerating to maintain grain temperatures within 15°F of average outdoor temperatures. These references also usually discourage the use of aeration to cool grain below freezing.

Grain Protectants

Application of insecticides directly to grain to prevent insect infestation is warranted if grain is to be stored more than 3 to 6 weeks at grain temperatures above 60° to 70°F. Summer-harvested grains that are to be stored 1 month or more and fall-harvested grains that are to remain in storage beyond May or June of the year following harvest should be treated with a protectant insecticide. Incorporating a surface treatment is adequate for short-term protection. However, uniform application to all grain at the auger is necessary for long-term protection. Where grain protectant insecticides are applied at labeled rates, grain can be processed or fed to livestock with no waiting period.

In order to protect against stored-grain beetles and weevils throughout the entire mass of grain within a bin, a protectant insecticide must be applied uniformly to all grain as it is augered into the bin. Drip-on or spray-on applicators can be mounted on the auger to apply liquid formulations. Dusts can be applied using an auger-mounted applicator, or they can be spread over a truck or wagon just before unloading. Protectant insecticides should not be applied to grain before high-temperature drying. Once grain is in the bin, surface or "cap-off" applications of protectant insecticides are effective only against the insects that are feeding at the grain surface. A surface dressing or "cap-off" treatment may be used to give some control of insects entering the top of the grain mass. Surface treatments often provide adequate protection where previously uninfested grain is to be stored at warm temperatures for a month or two. For longer storage at warm temperatures, adequate control requires treating the entire grain mass at the auger as the grain is binned. Table 1 summarizes uses for registered grain protectants.

Crop-specific recommendations for the use of protectant insecticides are:

Corn. It is not necessary to apply any insecticide to new-crop corn that will be removed from storage by May or June of the following spring. Similarly, if corn will be used on site as livestock feed (and not subject to grading associated with sale) within one year of harvest, use of a protectant insecticide usually is not necessary. For storage periods of 1 year or longer, apply Actellic or malathion at the loading auger using rates listed in Table 1. Reldan is not registered for use on corn. Do not apply insecticides before high-temperature drying because extreme heat will result in rapid volatilization and reduction in residues. For malathion residues to persist on corn at effective levels through the summer following harvest, corn must be dried to approximately 12 percent moisture. Data indicate Actellic residues will persist for a similar period on grain stored at 14 percent moisture.

Malathion will not control Indianmeal moth. Where malathion is applied at the auger as corn is binned, incorporate *B.t.* in the top 4 to 6 inches of the grain once the bin is filled and levelled or by May of the following spring to prevent infestation by Indianmeal moth larvae. Diatomaceous earth may also be used as a topdress treatment to control Indianmeal moth larvae.

Long-term storage programs usually allow "rotating" corn in storage — shipping out old corn and replacing it with the new crop each year. Annual rotation of stored corn helps to avoid buildup of insect infestations. Where annual rotation is practiced, topdress treatments of malathion plus *B.t.* or Actellic alone applied in April or May usually provide adequate control without treating the entire grain mass.

Soybeans. Only Indianmeal moth will infest soybeans stored at moisture levels that prevent mold growth. To protect against Indianmeal moth infestation, rake in surface applications of *B.t.* or diatomaceous earth once the bin is filled and levelled or by May of the following year. No other protectant insecticides are registered for application to stored soybeans.

Wheat. Wheat is especially vulnerable to insect infestation because it is harvested in midsummer when stored-product insects are active within and outside storage facilities. Warm temperatures in summer-harvested wheat also contribute to the rapid development and reproduction of insects within bins.

Apply malathion or Reldan at the loading auger to all wheat that is to be stored for 1 month or more. Where malathion is used, also incorporate *B.t.* or diatomaceous earth in the top 4 to 6 inches of grain to prevent Indianmeal moth infestations. Reldan controls Indianmeal moth and the weevils and "secondary" beetles that infest grain.

Sorghum. For storage periods of 1 year or longer, apply Actellic, malathion, or Reldan at the loading auger, but not before high-temperature drying. For malathion residues to persist at effective levels through the summer following harvest, grain must be dried to 12 percent moisture content; Actellic and Reldan should persist for 12 months or more on 14 percent moisture sorghum. Where malathion is applied, also rake in surface applications of *B.t.* or diatomaceous earth once the bin is filled and levelled or by May to control Indianmeal moth. Where sorghum has not been treated at the auger as it was binned, topdress applications of Actellic, Reldan, or malathion plus *B.t.* usually will provide adequate protection for one summer's storage if application is made by April or May.

Insecticide Resistance in Stored-Grain Insects

Insecticide resistance is an important worldwide problem that is especially common (on an international

Table 1. Insecticides registered for use to protect stored grain. Grains treated with protectant insecticides at labeled rates as specified below can be fed to livestock or processed for feed or food uses with no waiting period.

Insecticide	Registered for use on:	Rate/1,000 bu	Restrictions; Comments
malathion 57% EC, 6% D, 4% D, and 2% D	corn, wheat, oats, barley, rye, sorghum, sunflower	1 pt 57% EC in 2-5 gal water; 10 lb 6% dust; 15 lb 4% dust; or 30 lb 2% dust. Use the same amount/1,000 sq ft of grain surface as a "cap-off" treatment *if the entire grain mass is not treated.*	Do not apply to soybeans. **Malathion will not control Indianmeal moth.** Dry grain to 12% moisture in order for malathion to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
chlorpyrifos-methyl (Reldan 4E, 3%D)	wheat, oats, barley, sorghum	barley — 9.2 fl oz; oats — 6.2 fl oz; sorghum — 10.7 fl oz; wheat — 11.5 fl oz. Apply in 1 to 5 gal water. Use 10 lb 3% dust/1,000 bu. Use 1.6 to 3.0 fl oz 4E or 7 lb 3% dust/1,000 sq ft of grain surface as a "cap-off" treatment *if the entire grain mass is not treated.*	Do not apply to corn or soybeans. Controls weevils, secondary beetles, and Indianmeal moth. Dry grain to 14% moisture in order for chlorpyrifos-methyl to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
Bacillus thuringiensis (Bactospeine, Dipel, SOK-Bt, and Thuricide)	corn, soybeans, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Use to control Indianmeal moth larvae. Controls only larval stages; must be ingested. Apply to the top 4 to 6 inches of grain as it is augered into the bin or incorporate by raking once the bin is filled.
pirimiphos-methyl (Actellic 5E)	corn (including popcorn), sorghum	8.6 to 11.5 fl oz in 5 gal water. Use 3 fl oz in 2 gal water/1,000 sq ft surface area as a "cap-off" treatment *if the entire grain mass is not treated.*	Do not apply to soybeans, wheat, barley, or oats. Controls weevils, secondary beetles, and Indianmeal moth. Dry grain to 14% moisture for pirimiphos-methyl to persist for 1 year or more. Do not apply before high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
diatomaceous earth	corn, wheat, oats, barley, rye, sorghum, soybeans, sunflower	Follow label directions.	See text, page 6.
methoprene (Diacon, 65.7% a.i.)	corn, wheat, sorghum, barley, oats	wheat — 7.7 fl oz; corn and sorghum — 7.1 fl oz; barley — 6.1 fl oz; oats — 4.1 fl oz. Apply in 5 gal water.	Do not apply to soybeans. Prevents normal development of immature stages of insects but will not kill adult insects. Apply as a preventative. Do not apply more than once per crop.
pyrethrins plus piperonyl butoxide	corn, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Do not apply to soybeans. Short-term residual activity. Useful mainly as a surface spray to control larval and adult Indianmeal moths as well as other pests at the grain surface.

scale) in stored-product insects. In Illinois, resistance to malathion is widespread among Indianmeal moth populations throughout the state. Some Illinois populations of the red flour beetle are resistant to malathion, but the range and intensity of this resistance problem in Illinois are not well known. Populations of the hairy fungus beetle collected in northern Illinois are resistant to both Actellic and malathion; the geographical range of resistant populations of this species is not known.

Special Review of Dichlorvos

Resin strips containing the insecticide dichlorvos (DDVP, Vapona) have been used for several years in grain storages to control the adult Indianmeal moth in the storage headspace. Originally known as "No-Pest Strips," these insecticide devices have been sold under several trade names.

As a result of studies commissioned by the National Toxicology Program, the U.S. Environmental Protection Agency (U.S. EPA) has recently classified dichlorvos as a probable human carcinogen. The U.S. EPA has initiated a "Special Review" of dichlorvos to evaluate the benefits and risks associated with its use in a variety of pest control situations. The results of that review will determine the future of dichlorvos registrations and uses.

Until further information clarifies the risks associated with the use of dichlorvos, and until the Special Review results in continuation or cancellation of current registrations, grain handlers are advised to discontinue the use of dichlorvos for stored-product insect control.

Methoprene

The U.S. EPA recently approved registration of the insect growth regulator methoprene (trade name Diacon) for use on stored grains (but not soybeans). Methoprene is a compound similar to the naturally occurring juvenile hormones of insects. Its acute toxicity to mammals is very low. The active ingredient methoprene interferes with the growth and maturation of immature stages of insects. It will not control adult insects already present in grain, but it will prevent immature stages from developing to adults and reproducing. Insects listed on the Diacon label include the Indianmeal moth, cigarette beetle, lesser grain borer, sawtoothed grain beetle, merchant grain beetle, red flour beetle, and confused flour beetle.

Current labeling for Diacon allows its use as an empty-bin spray and as a direct spray on grain as it is augered or conveyed into storage; no instructions for surface topdress application are included on the Diacon label. Because methoprene does not kill adult insects, this compound should not be used to provide rapid control of existing infestations.

Diatomaceous Earth

Diatomaceous earth is an abrasive and slightly sorptive dust that damages an insect's body covering and causes death by dehydration. Applied at high rates (120 to 300 lb/1,000 bushels of grain), diatomaceous earth is a fairly effective protectant against several stored-grain insects. Labels for the diatomaceous earth product Insecto recommend application of 28 to 56 lb/1,000 bushels of corn. Field data supporting the effectiveness of rates in this range are lacking. For long-term protection, diatomaceous earth must be applied at the auger as grain is binned so that it is distributed evenly throughout the grain mass within a storage. Incorporating surface treatments should provide some control of insects active in the treated layer. Labels for Insecto recommend monthly applications of 1 lb/1,000 sq ft of surface area; field data supporting the efficacy of this low rate are lacking. Problems associated with the use of diatomaceous earth as a grain protectant include increased wear to grain-moving equipment, the generation of great amounts of airborne dust during grain handling, and possible reductions in grain grade and test weight. Some buyers refuse to accept grain treated with diatomaceous earth. One successful and practical use of diatomaceous earth has been its addition to small seed packets to prevent infestation by stored-product pests.

SAMPLING STORED GRAIN

Stored grain should be monitored regularly to determine grain moisture content and temperature and to detect any insect infestations. Sample stored grain for insects at least monthly from November through April and at least twice monthly from May through October. Pay particular attention to the grain surface and the central core of the grain mass, but also sample additional locations and depths. Be sure to examine grain from any locations where temperature or moisture readings are substantially higher than average. Deep bin probes and sectioned grain triers are most commonly used for withdrawing samples from beneath the grain surface. Probe traps and sticky pheromone traps also are available for monitoring insects within the grain mass and flying moths, respectively. Sampling equipment is available from most bin sales and service companies.

CONTROLLING ESTABLISHED INFESTATIONS

When insects are found in stored grains, a logical question is "Are there enough insects present to warrant control?" Unfortunately, this question is hard to answer. The importance of an insect infestation is determined not only by insect numbers, but also by type of grain, insect species, time of year, grain temperature and moisture, the planned duration of storage, market potential, and local elevator quality and dockage guidelines. Revised (1988) Federal Grain Inspection Service (FGIS) standards for grain insect infestation are presented in Table 2, but local elevators usually enforce more stringent standards. Insect-damaged kernels also may result in price discounts. Consider too that insect populations and their damage can increase rapidly.

When insects are detected in stored grain, consider several possible management practices. Sometimes the most profitable action can be to clean and sell the grain immediately without any chemical treatment. Immediate sale can be especially appropriate where early stages of insect infestations are detected before insect numbers reach elevator detection or discount levels. During cool weather, aerating to cool the grain to below 50°F can prevent insect activity and allow an extended period of safe storage.

Sometimes insect problems may be limited primarily to the surface or central core of stored grain. If Indianmeal moth is the only problem, light infestations can

Table 2. The number of live insects (per kilogram of grain) required for FGIS designation as "infested"

Crop	Insect density for designation as "infested"
Wheat, Rye, Triticale	• More than 1 live weevil, or • One live weevil plus any other live stored grain insect pest, or • No live weevils, but 2 or more other live pest insects.
Corn, Barley, Oats, Sorghum, and Soybeans	• More than 1 live weevil, or • One live weevil plus 5 or more other live pest insects, or • No live weevils, but 10 or more other live pest insects.

be controlled by using *B.t.*, Actellic, Reldan, or diatomaceous earth as outlined in Table 1. Unincorporated applications of these insecticides will not control Indianmeal moth larvae already present a few inches below the grain surface. Where abundant webbing indicates a severe infestation, webbing should be raked from the surface before treating; fumigation may be necessary in these situations. Where secondary beetles are confined primarily to a central core of fine material, removing 1 or 2 loads of grain to extract that core can allow safe storage of the remaining grain.

Where infested grain can be moved to a clean bin, transfer and treatment with a protectant insecticide (see Table 1) is recommended. If possible, use a grain cleaner during the transfer process. Protectant insecticides will not immediately kill immature insects within grain kernels, but residues will eventually provide control and protect against reinfestation for a period dependent upon grain moisture and temperature.

Infested grain that cannot be treated successfully in any other way should be fumigated. The U.S. Environmental Protection Agency has prohibited the use of fumigants containing ethylene dibromide (EDB), ethylene dichloride (EDC), carbon bisulfide, or carbon tetrachloride.

Suspension of most liquid fumigant registrations, coupled with increased safety concerns and protective equipment requirements for remaining fumigants, signals the fact that fumigation of farm-stored grain is a potentially dangerous and difficult operation. Hiring a professional fumigator is recommended, especially for fumigation of bins with capacities greater than 5 to 10 thousand bushels.

Fumigation Steps

Persons not trained and certified specifically in the use of grain fumigants should not attempt to fumigate stored grain. The steps outlined below provide general guidelines, but not complete directions.

1. Level the surface of the grain, break up any caked or crusted areas, and remove any surface webbing.

2. Use tape and plastic sheeting to thoroughly seal all cracks and holes in the bin; seal the side door, unloading auger shaft, and fan openings. If the grain surface will not be tarped, also seal the eaves and roof hatches. Leave only the necessary access openings to seal after fumigant application. If the grain surface is to be tarped, tuck the plastic tarp along one edge of the structure so that it can be rolled out easily once the fumigant has been applied.

3. Spray the outside surface of the bin with malathion (4 fl oz 57% EC/gal water), chlorpyrifos-methyl (4 fl oz Reldan 4E/3 gal water), or methoxychlor (1 qt 25% EC or 12 oz 50% WP/2 gal water).

4. Learn and follow all safety precautions. Always work in pairs; an observer should be present *outside* of the bin. The U.S. Environmental Protection Agency recently revised fumigant regulations. New labeling requires the use or availability of a self-contained breathing apparatus for respiratory protection during one or more stages of the fumigation process. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific label directions concerning respiratory protection equipment and gas detection devices. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

5. Choose a calm, warm day when the grain temperature is above 60°F. Apply a liquid or solid fumigant. Only those fumigants containing aluminum phosphide are registered for use on soybeans.

Chloropicrin (Chlor-o-pic, Larvacide 100, and Quasar) is a restricted-use liquid fumigant labeled for probe and surface application to stored grain. Protective clothing and respiratory equipment must be worn during application. Use 2.5 lb/1,000 bushels of wheat, barley, or rice; 3.0 lb/1,000 bushels of corn; 3.5 lb/1,000 bushels of oats; or 4.5 lb/1,000 bushels of grain sorghum. To provide successful control, chloropicrin must be applied by probes into the grain mass and uniformly onto burlap bags spread over the grain surface. Wait at least 72 hours before airing out; fumigated grain must be thoroughly aerated before processing or feeding.

Chloropicrin's use as a grain fumigant is scheduled to be discontinued. Its use as an empty-bin fumigant will not be altered by this action.

Dry fumigants containing aluminum phosphide include Detia, Fumitoxin, Gastoxin, Phostek, and Phostoxin. Aluminum phosphide is a restricted-use fumigant. A special application probe is required to place aluminum phosphide tablets or pellets in the grain mass. Use 180 tablets or 300 pellets per 1,000 bushels of bin capacity. Do not allow water to come in contact with tablets or pellets; wear neoprene or cotton gloves to prevent perspiration from reaching the dry material. During application, fumigant concentrations must be monitored using detector tubes to determine the need for respiratory protection.

6. Following application, finish tarping the grain surface or seal the access door that served as an exit from the bin. Place warning signs as directed by the fumigant label.

7. Wait at least 72 hours before airing out bins following aluminum phosphide or chloropicrin application; follow label directions. After aeration, fumigant concentrations must be measured before warning placards can be removed and before the grain can be fed or processed.

An additional fumigant that is effective and registered for application to stored grain is methyl bromide. Safety concerns and equipment requirements limit the use of methyl bromide to application by professional fumigators.

The atmospheric gases carbon dioxide and nitrogen (alone or in combination) can be used successfully as grain fumigants. These gases are supplied for fumigation by stationary or portable generators or delivered in pressurized tanker trucks. The fumigant gas must be introduced into a storage in a manner that displaces the original air volume; then an adequate concentration (usually around 40 to 60 percent by volume) must be maintained for a period of 4 to 10 days (longer in cool grain). For these reasons, thorough sealing is especially important. Fumigation with atmospheric gases leaves no toxic residues once the treated commodity is aerated, but it is important to remember that carbon dioxide concentrations reach toxic levels in work areas during application. Applicators and other workers must wear respiratory protection (a self-contained breathing apparatus) during periods of exposure. Fumigation using atmospheric gases is currently conducted by only a few professional fumigators and by a few large grain companies that maintain equipment at their storage sites. Where available, fumigation with carbon dioxide and/or nitrogen can be cost-competitive and effective.

Once it is aired out, fumigated grain is subject to reinfestation. Surface application of a protectant insecticide should precede or follow fumigation if storage is to continue.

Beneficial Insects

One or more companies are marketing a program that calls for periodic releases of beneficial insects (predators and parasites of pest species) for pest management in stored grains. Although considerable research has been directed at this practice, questions concerning the ability of beneficial releases to lower pest populations to levels required by current grading standards remain unanswered. Published studies conducted in on-farm storages have not achieved adequate levels of control. Farmers and grain handlers who purchase beneficial insects for stored-grain pest management are urged to monitor results very closely.

Where management efforts must be limited to "non-chemical" methods of control, sound cultural practices (sanitation, adequate drying, cleaning, aeration, and annual rotation of the commodity) are extremely important.

SPECIAL CONSIDERATIONS FOR STORED SEEDS

Seed corn in bulk storage (in cribs, bins, granaries, etc.) can be protected from insect damage by using the storage practices and protectant insecticides discussed previously. These practices include proper sanitation, drying, cleaning, and temperature management (aeration) and the use of protectant insecticides such as pirimiphos-methyl (Actellic), malathion, *B.t.*, and pyrethrin plus piperonyl butoxide. Where fumigation of bulk-stored seed corn is necessary, aluminum phosphide fumigants or carbon dioxide can be used effectively without affecting seed germination. Methyl bromide and chloropicrin reduce or destroy seed germination.

In bagged seed corn (usually not treated with any insecticides) several stored-grain insects may be a problem, but the Indianmeal moth is the most common. Although bulk seed treatments using Actellic or *B.t.* provide residual control of Indianmeal moth larvae, such treatments must be applied before or during bagging. Small quantities of valuable seed can be protected by cool storage or by adding diatomaceous earth to seed packets.

To limit the invasion of untreated, bagged seed corn, warehouses can be fogged periodically during the summer using pyrethrins plus piperonyl butoxide. Using proper warehouse sanitation methods, maintaining cool temperatures, and excluding pests (by using screens, tight-fitting doors and windows, caulking, etc.) also are important. Bagged seed can be effectively fumigated using aluminum phosphide fumigants. Hiring a professional fumigator is advised.

REFERENCES

Stored Grain Insects. 57 pp. USDA Agricultural Handbook No. 500. Available for $4.50 from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Fact Sheets available from Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

NHE 62 — *Angoumois Grain Moth*
NHE 63 — *Indianmeal Moth*
NHE 64 — *Granary and Rice Weevil*
NHE 65 — *Grain and Flour Beetles*

Picture Sheet X798.01, Stored Grain Insects and Molds. Available for purchase from Vocational Agriculture Services, University of Illinois, 1401 South Maryland Drive, Urbana, IL 61801.

Pesticide Applicator Training Packet — Grain Facility Pest Control. Available for $6.00 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

Illinois Pesticide Applicator Training Manual for Seed Treatment — SP39-1. Available for $2.00 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

For a list of addresses of suppliers of insect traps, other sampling equipment, and insecticide application equipment (for stored grains), write to the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

Microbial Insecticides

SYNTHETIC CHEMICAL INSECTICIDES provide many benefits to food production and human health, but they also pose some hazards. In many instances, alternative methods of insect management offer adequate levels of pest control and pose fewer hazards. One such alternative is the use of microbial insecticides—insecticides that contain microorganisms or their by-products. Microbial insecticides are especially valuable because their toxicity to nontarget animals and humans is extremely low. Compared to other commonly used insecticides, they are safe for both the pesticide user and consumers of treated crops. Microbial insecticides also are known as biological insecticides, bio-rational insecticides, insect pathogens, and biological control agents.

Microbial insecticides are comprised of microscopic living organisms (viruses, bacteria, fungi, protozoa, or nematodes) or the toxins produced by these organisms. They are formulated to be applied as conventional insecticidal sprays, dusts, or granules. Each product's specific properties determine the ways in which it can be used most effectively. This publication, one of a series on alternative methods of insect management, has been developed to help readers make the most effective use of microbial insecticides. It summarizes the strengths and weaknesses of products available commercially (and a few still under development), describes the types of microorganisms formulated for insect control, and lists the most promising uses for microbial insecticides.

With the exception of insecticidal products containing nematodes, all the microbial insecticides discussed in this publication are regulated by the United States Environmental Protection Agency (US EPA). (Nematodes used for insect control are multicellular parasites, and parasites and predators are not regulated as pesticides by the US EPA.) Although this publication provides background information on microbial insecticides, readers should consult product labels for specific application directions. All insecticides should be used only in the manner specified on the product label.

Advantages of Microbial Insecticides

Individual products differ in important ways, but the following list of beneficial characteristics applies to microbial insecticides in general.

- The organisms used in microbial insecticides are essentially nontoxic and nonpathogenic to wildlife, humans, and other organisms not closely related to the target pest. The safety offered by microbial insecticides is their greatest strength.
- The toxic action of microbial insecticides is often specific to a single group or species of insects, and this specificity means that most microbial insecticides do not directly affect beneficial insects (including predators or parasites of pests) in treated areas.
- If necessary, most microbial insecticides can be used in conjunction with synthetic chemical insecticides because in most cases the microbial product is not deactivated or damaged by residues of conventional insecticides. (Follow label directions concerning any limitations.)
- Because their residues present no hazards to humans or other animals, microbial insecticides can be applied even when a crop is almost ready for harvest.
- In some cases, the pathogenic microorganisms can become established in a pest population or its habitat and provide control during subsequent pest generations or seasons.

NOTE: The information in this circular is provided for educational purposes only. Trade names of insecticides have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois or the Illinois Department of Energy and Natural Resources. Discrimination is not intended against any product. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

Prepared by Rick Weinzierl and Tess Henn, Office of Agricultural Entomology,
University of Illinois at Urbana-Champaign,
College of Agriculture, Cooperative Extension Service,
in cooperation with the Illinois Natural History Survey

Circular 1295
September 1989

Disadvantages of Microbial Insecticides

The limitations or disadvantages listed below do not prevent the successful use of microbial insecticides. Understanding how these limitations affect specific microorganisms will help users to choose effective products and take necessary steps to achieve successful results.

- Because a single microbial insecticide is toxic to only a specific species or group of insects, each application may control only a portion of the pests present in a field, garden, or lawn. If other types of pests are present in the treated area, they will survive and may continue to cause damage. Conventional insecticides are subject to similar limitations because they too are not equally effective against all pests. Nonetheless, the negative aspect of selectivity is often more noticeable for microbials.
- Heat, desiccation (drying out), or exposure to ultraviolet radiation reduces the effectiveness of several types of microbial insecticides. Consequently, proper timing and application procedures are especially important for some products.
- Special formulation and storage procedures are necessary for some microbial pesticides. Although these procedures may complicate the production and distribution of certain products, storage requirements do not seriously limit the handling of microbial insecticides that are widely available. (Store all pesticides, including microbial insecticides, according to label directions.)
- Because several microbial insecticides are pest-specific, the potential market for these products may be limited. Their development, registration, and production costs cannot be spread over a wide range of pest control sales. Consequently, some products are not widely available or are relatively expensive (several insect viruses, for example).

BACTERIA

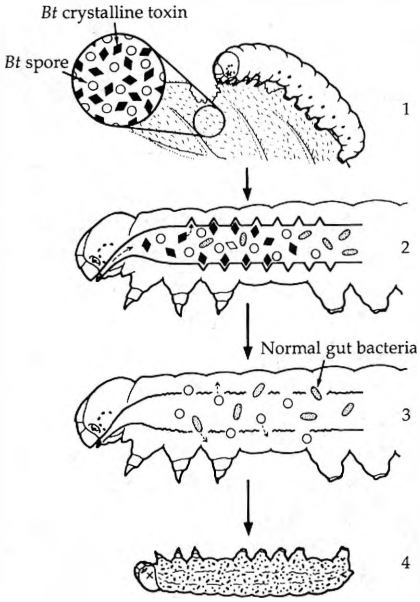
Bacterial pathogens used for insect control are spore-forming, rod-shaped bacteria in the genus *Bacillus*. They occur commonly in soils, and most insecticidal strains have been isolated from soil samples. Bacterial insecticides must be eaten to be effective; they are not contact poisons. Insecticidal products comprised of a single *Bacillus* species may be active against an entire order of insects, or they may be effective against only one or a few species. For example, products containing *Bacillus thuringiensis* var. *kurstaki* kill the caterpillar stage of a wide array of butterflies and moths. In contrast, *Bacillus popillae* (milky spore disease) kills Japanese beetle larvae but is not effective against the closely related annual white grubs (masked chafers in the genus *Cyclocephala*) that commonly infest lawns in Illinois.

The microbial insecticides most widely used in the United States since the 1960s are preparations of the bacterium *Bacillus thuringiensis* (abbreviated as *Bt*). *Bt* products are produced commercially in large industrial fermentation tanks. As the bacteria live and multiply in the right conditions, each cell produces (internally) a spore and a crystalline protein toxin called an endotoxin. Most commercial *Bt* products contain the protein toxin and spores, but some are cultured in a manner that yields only the toxin component.

When *Bt* is ingested by a susceptible insect, the protein toxin is activated by alkaline conditions and enzyme activity in the insect's gut. The toxicity of the activated toxin is dependent on the presence of specific receptor sites on the insect's gut wall. This necessary match between toxin and receptor sites determines the range of insect species killed by each *Bt* subspecies and isolate. If the activated toxin attaches to receptor sites, it paralyzes and destroys the cells of the insect's gut wall, allowing the gut contents to enter the insect's body cavity and bloodstream. Poisoned insects may die quickly from the activity of the toxin or may die within 2 or 3 days from the effects of septicemia (blood-poisoning). Although a few days may elapse before the insect dies, it stops feeding (and therefore stops damaging crops) soon after ingesting *Bt*.

Bt does not colonize or cycle (reproduce and persist to infect subsequent generations of the pest) in the environment in the magnitude necessary to provide continuing control of target pests. The bacteria may multiply in the infected host, but bacterial multiplication in the insect does not result in production of abundant spores or crystalline toxins. The usual result is that few or no infective units are released into the environment when a poisoned insect dies. Consequently, *Bt* products are applied much like synthetic insecticides. *Bt* treatments are inactivated fairly rapidly (within one to a few days) in many outdoor situations, and repeated applications may be necessary for some crops and pests.

Action of *Bacillus thuringiensis* var. *kurstaki* on caterpillars



(1) Caterpillar consumes foliage treated with *Bt* (spores and crystalline toxin). (2) Within minutes, the toxin binds to specific receptors in the gut wall, and the caterpillar STOPS FEEDING. (3) Within hours, the gut wall breaks down, allowing spores and normal gut bateria to enter the body cavity; the toxin dissolves. (4) In 1-2 days, the caterpillar dies from septicemia as spores and gut bacteria proliferate in its blood.

Adapted from Abbot Laboratories, "Mosquito Control: Taking the Bite Out of Summer"

Caterpillar Targets for *Bt*:

Common caterpillar pests that are controlled effectively with *Bacillus thuringiensis* var. *kurstaki* (*Bt*) include

- European corn borer in corn
- Indianmeal moth in stored grain
- cabbage looper
- imported cabbageworm
- diamondback moth
- tomato/tobacco hornworm
- gypsy moth
- spruce budworm
- tent caterpillars
- fall webworm
- mimosa webworm
- bagworms
- spring and fall cankerworm

Common caterpillar pests that are NOT controlled by normal applications of *Bt* include

- corn earworm (on corn)
- codling moth
- peach tree borer
- squash vine borer

Until the early 1980s, commercial *Bt* products were effective only against caterpillars. In recent years, however, additional isolates that kill other types of pests have been identified and developed for insecticidal use. The nature of the crystalline protein endotoxin differs among *Bt* subspecies and isolates, and it is the characteristics of these specific endotoxins that determine what insects will be poisoned by each *Bt* product. *Bt* formulations that are now commercially available fall into one of the following broad categories.

***Bt* formulations that kill caterpillars.** The best-known and most widely used *Bt* insecticides are formulated from *Bacillus thuringiensis* var. *kurstaki* isolates that are pathogenic and toxic only to larvae of the butterflies and moths. Many such *Bt* products have been registered with the United States Environmental Protection Agency. The most common trade names for these commercial products include Dipel®, Javelin®, Thuricide®, Worm Attack®, Caterpillar Killer®, Bactospeine®, and SOK-Bt®, but many small companies sell similar products under a variety of trade names. These products are commercially successful and widely available as liquid concentrates, wettable powders, and ready-to-use dusts and granules. They are used to control many common leaf-feeding caterpillars, including caterpillar pests on vegetables (especially the "worms" that attack cabbage, broccoli, cauliflower, and Brussels sprouts), bagworms and tent caterpillars on trees and shrubs, larvae of the gypsy moth and other forest caterpillars, and European corn borer larvae in field corn. Several of these products are used to control Indianmeal moth larvae in stored grain. One product with a very specific target is Certan®, formulated from *Bacillus thuringiensis* var. *aizawai*, and used exclusively for the control of wax moth larvae in honeybee hives.

Bt products that kill caterpillars are NOT effective against other types of pests; they will not control aphids, beetles, flies, or additional pests other than caterpillars. Even certain caterpillars are not effectively controlled by *Bt*, especially those that live in the soil or bore into plant tissues without consuming a significant amount of the *Bt* applied to plant surfaces. (Again, *Bt* is a stomach poison that must be ingested to be effective.) The peach tree borer in stone fruits, corn earworm in corn, and the cutworms that clip off field crops or garden plants are examples of caterpillars seldom controlled by *Bt* treatments. *Bt* is not registered for the control of codling moth larvae that attack apples and pears because these larvae do not feed much (if at all) on treated surfaces.

***Bt* formulations that kill mosquito, black fly, and fungus gnat larvae.** Production of a second group of *Bt* insecticides began in the early 1980s. These products utilize *Bacillus thuringiensis* var. *israelensis* (*Bti*), a subspecies that kills the larvae of certain Diptera (the insect order containing the flies and mosquitoes). The main targets for *Bti* are the larval stages of mosquitoes, black flies, and fungus gnats; it does not control larval stages of "higher" flies such as the house fly, stable fly, or blow flies. Mosquitoes that are most susceptible to *Bti* include species in the genera *Aedes* and *Psorophora*. *Anopheles* and *Culex* species are controlled only when higher than normal rates of *Bti* are applied. *Bti* products that are available commercially include Vectobac®, Teknar®, Bactimos®, Skeetal®, and Mosquito Attack®.

Bti is most effective for mosquito or black fly control when it is used on a community-wide basis by mosquito abatement district personnel. In general, any attempts to reduce the prevalence of mosquito-breeding sites and treat remaining sites are most effective when undertaken on such a scale. For most homeowners or farmers, eliminating sites that periodically serve as sources of standing water (such as tires and empty containers) and controlling weeds around ponds or drainage lagoons is more effective than applying *Bti*.

Bti products are formulated for spray or granular applications. *Bti* formulated on corn cob granules is effective against mosquito larvae developing in tires and other artificial containers. (The "Asian tiger mosquito," *Aedes albopictus*, develops in these containers.) The corn cob granules can be blown into tire piles to provide good penetration and uniform treatment; residual control is also greater when corn cob granules are used. *Bti* is not very effective for the control of mosquito larvae in turbid water or waters containing high levels of organic pollutants.

Bti has also been used effectively for the control of fungus gnat larvae in greenhouses and in mushroom culture beds. For these uses, *Bti* is applied as a drench to potting soils or culture media. Not all *Bti* products are labeled for fungus gnat control.

Although not a *Bt*, another bacterium that is pathogenic to certain mosquitoes is *Bacillus sphaericus*. *Bacillus sphaericus* is especially active against larvae of mosquitoes in the genera *Culex*, *Psorophora*, and *Culiseta*. Effectiveness against larvae of *Aedes* species varies. *Aedes vexans* is very susceptible, but *Aedes aegypti* (the yellow fever mosquito) and *Aedes albopictus* are not. *Bacillus sphaericus* kills *Anopheles* larvae in laboratory tests, but field results have not been promising. Because *Anopheles* mosquitoes are true surface feeders, the bacterium would have to remain on the water surface for an extended period to be effective. *Bacillus sphaericus* formulations tested up to now do not remain at the surface long enough to be effective.

In addition to infecting a different group of mosquito species than *Bti*, *Bacillus sphaericus* is a potentially valuable insecticide because it remains effective in stagnant or turbid water. Although *Bacillus sphaericus*; as it occurs naturally, does cycle and maintain itself in the environment, insecticidal formulations currently under development do not cycle in water to infect subsequent generations of mosquito larvae. EPA registration of *Bacillus sphaericus* is pending.

***Bt* formulations that kill beetles.** Another group of *Bt* isolates, including those from *Bacillus thuringiensis* var. *san diego* and *Bacillus thuringiensis* var. *tenebrionis*, are toxic to certain beetles. Within the order Coleoptera (the beetles), species exhibit great differences in susceptibility to these isolates, presumably because of differences in the insects' gut wall receptor sites where the bacterial toxins must attach. Consequently, the range of susceptible hosts for the beetle-targeted *Bt* formulations does not include all beetles, or even all of the species within a beetle family or subfamily.

In 1988, *Bacillus thuringiensis* var. *san diego*, sold under the trade name M-One®, was first registered for use against larvae of the Colorado potato beetle. This product also kills elm leaf beetle adults and larvae, but it is not pathogenic or toxic to some other key beetle pests, such as the corn rootworms and other related species. Registration of Trident®, a very similar product containing *Bacillus thuringiensis* var. *tenebrionis*, is pending. Considerable research effort is now directed to identifying and developing additional *Bt* isolates that are active against more or different beetle species. Although entomologists and consumers alike will need to consider the specific target insect when judging the potential for these new products, *Bt* formulations effective against beetles seem to offer great promise.

Using *Bt* insecticides. Insecticides containing *Bt* can be very effective for insect control in a variety of situations. Reviewing a few key facts about these products can help users obtain the best results possible. Each *Bt* insecticide controls only certain types of insects; therefore, it is essential to identify the target pest and to confirm that the *Bt* product label states that the insecticide is effective against that pest. Separate stages of insects differ in their susceptibility to *Bt*; isolates that are effective against larval stages of butterflies, moths, or mosquitoes will not kill adults. Because susceptible insects must consume *Bt* to be poisoned, treatments must be directed to the plant parts or other material that the target pest will eat. Where this is not possible (for example, where pests bore into plant tissue without feeding much on the surface of foliage or fruits), *Bt* is usually not very effective. *Bt* does not kill susceptible insects immediately. Poisoned insects normally remain on plants for a day or two after treatment, but they do not continue feeding and will die soon.

Where *Bt* is applied to plant surfaces or other sites exposed to sunlight, it is deactivated rapidly by direct ultraviolet radiation. To maximize the effectiveness of *Bt* treatments, sprays should thoroughly cover all plant surfaces, including the undersides of leaves. Treating in the late afternoon or evening can be helpful because the insecticide remains effective on foliage overnight before being inactivated by exposure to intense sunlight the following day. Treating on cloudy (but not rainy) days provides a similar result. Production processes that encapsulate *Bt* spores or toxins in a granular matrix (such as starch) or within killed cells of other bacteria also provide protection from ultraviolet radiation. Registration and sale of products containing encapsulated *Bt* are forthcoming.

Some *Bt* isolates (not those used in currently available insecticides) produce significant amounts of an additional toxin called thuringiensin, an exotoxin that is released outside the bacterial cell wall. Research is underway to develop commercial insecticides containing this toxin. Although thuringiensin might be lauded as "natural" because it is produced by living organisms, it is nonetheless toxic to a wide range of animal species and humans. As thuringiensin insecticides are registered and become available, users should recognize the difference between thuringiensin and other *Bt* products. Thuringiensin is much more toxic and should be handled much more cautiously.

Although the issue of thuringiensin's toxicity to mammals is a unique characteristic that does not detract from the overall safety of registered microbial insecticides, users are advised to handle all microbial insecticides cautiously. Bacterial spores, mold spores, and virus particles become "foreign proteins" if they are inhaled or rubbed into the skin. As such, they can cause serious allergic reactions. The dusts or liquids used to dilute and carry these microorganisms also can act as allergens or irritants. These problems do not prevent the safe use of microbial insecticides, but they do mean that users should not breathe dusts or mists of microbial insecticides. Users should wear gloves, long sleeves, and long trousers during application and wash thoroughly after completing the application. These are commonsense precautions that will help to prevent unexpected reactions and minimize any effects from unknown toxicity.

Recent advances in biotechnology have resulted not only in improved prospects for developing new *Bt* insecticides but also in an ability to place *Bt* toxins within crop plants in a variety of ways. For example, genes directing the production of *Bt* toxins can be incorporated into certain plant-dwelling bacteria. When these altered bacteria grow and multiply within an inoculated host plant, the *Bt* toxin is produced within the plant. Efforts are underway to test this type of *Bt* "application" in corn to control the European corn borer. Although the development of this technology may seem ideal, the season-long, high-level control it would provide would also pose a great risk for the development of insect resistance to the *Bt* toxin. As genes for production of insecticidal compounds are added to crop plants, developers must also devise methods of preventing or managing insecticide resistance in target pests.

Other bacterial insecticides. Insecticides sold under the trade names Doom®, Japidemic®, Grub Attack®, and the generic name "milky spore disease" contain the bacteria *Bacillus popillae* and *Bacillus lentimorbus*. These bacteria cannot be grown in fermentation tanks; instead, they are "cultivated" in laboratory-reared insect larvae. Products containing *Bacillus popillae* and *Bacillus lentimorbus* can be applied to turf and "watered in" to the soil below to control the larval (grub) stage of the Japanese beetle and, less effectively, some other beetle grubs. When a susceptible grub consumes spores of these bacteria, they proliferate within it, and the grub's internal organs are liquified and turned milky white (hence the name, milky spore disease). These symptoms develop slowly, often over a period of three to four weeks following initial infection.

Bacillus popillae and *Bacillus lentimorbus*, unlike *Bt*, do cycle in the environment if a substantial grub population is present at the time of application. When grubs killed by these bacteria break apart, a new batch of spores is released into the soil. These spores can survive (waiting to infect another grub) beneath undisturbed sod for a period of 15 to 20 years. Consequently, lawn applications of milky spore disease bacteria might not have to be repeated each year.

Unfortunately, *Bacillus popillae* and *Bacillus lentimorbus* offer limited usefulness in Illinois and other Midwestern states because the predominant lawn grubs in this region are annual white grubs, which are larvae of beetles called chafers (genus *Cyclocephala*). These larvae are not susceptible (or are only slightly susceptible) to milky spore disease.

VIRUSES

The larvae of many insect species are vulnerable to devastating epidemics of viral diseases. The viruses that cause these outbreaks are very specific, usually acting against only a single insect genus or even a single species. Most of the viruses that have been studied for use as potential insecticides are nuclear polyhedrosis viruses (NPVs), in which numerous virus particles are "packaged" together in a crystalline envelope within insect cell nuclei, or granulosis viruses (GVs), in which one or two virus particles are surrounded by a granular or capsule-like protein crystal found in the host cell nucleus. These groups of viruses infect caterpillars and the larval stages of sawflies.

Viruses, like bacteria, must be ingested to infect insect hosts. In sawfly larvae, virus infections are limited to the gut, and disease symptoms are not as obvious as they are in caterpillars. In caterpillars, virus particles pass through the insect's gut wall and infect other body tissues. As an infection progresses, the caterpillar's internal organs are liquified, and its cuticle (body covering) discolors and eventually ruptures. Caterpillars killed by virus infection appear limp and soggy. They often remain attached to foliage or twigs for several days, releasing virus particles that may be consumed by other larvae. The pathogen can be spread throughout an insect population in this way (especially when rain drops help to splash the virus particles to adjacent foliage) and by infected adult females depositing virus-contaminated eggs. Dissemination of viral pathogens is deterred by exposure to direct sunlight, because direct ultraviolet radiation destroys virus particles. Although naturally occurring epidemics do control certain pests, these epidemics rarely occur before pest populations have reached outbreak levels.

The development and use of virus-based insecticides have been limited. Unlike *Bt*, insect viruses must be produced in live host insects. Production is therefore both expensive and time-consuming. Because viruses are genus- or species-specific, each viral insecticide has a limited market. These economic factors, coupled with the fact that some virus insecticides are considerably less effective than available synthetic chemical insecticides, have limited their development.

Nonetheless, although they are not well known or widely available, several insect viruses have been developed and registered for use as insecticides. Most are specific to a single species or a small group of related forest pests, for example the gypsy moth, Douglas-fir tussock moth, spruce budworm, and pine sawfly. They are not commercially available but are produced and used by the United States Forest Service. Forest pests are especially good targets for viral pathogens because the permanence of the forest environment contributes to cycling of the pathogen (transmission from one generation to the next). The forest canopy also helps to protect viral particles from destruction by ultraviolet radiation.

Other insect viruses investigated for use as insecticides include those that infect the alfalfa looper, soybean looper, armyworms, cabbage looper, and imported cabbageworm. Although some of these viruses have been formulated and applied in field tests, none has been registered or sold commercially. Both the codling moth GV (Decyde®) and the *Heliothis* NPV (Elcar®) were at one time registered by the US EPA and produced commercially, but these products are no longer registered or available.

If additional viral insecticides are registered or if currently registered products become more widely available, their effective use will depend upon applicators remembering the following key facts: Most viruses are host-specific and effective only against immature stages of the target species; users must be sure to match the pathogen and the target pest correctly. Virus particles are killed by ultraviolet radiation; treating in the evening or on cloudy days should increase their effectiveness.

FUNGI

Fungi, like viruses, often act as important natural control agents that limit insect populations. Most of the species that cause insect diseases spread by means of asexual spores called conidia. Although conidia of different fungi vary greatly in ability to survive adverse environmental conditions, desiccation and ultraviolet radiation are important causes of mortality in many species. Where viable conidia reach a susceptible host, free water or very high humidity is usually required for germination. Unlike bacterial spores or virus particles, fungal conidia can germinate on the insect cuticle and produce specialized structures that allow the fungus to penetrate the cuticle and enter the insect's body. Fungi do not have to be ingested to cause infections. In most instances, as fungal infections progress, infected insects are killed by fungal toxins, not by the chronic effects of parasitism.

Fungal pathogens differ in the range of life stages and species they are able to infect. Many important fungal pathogens attack eggs, immatures, and adults of a variety of insect species. Others are more specific to immature stages or to a narrow range of insect species.

Several factors have limited the development of fungal insecticides in the United States. Although fungal pathogens (at least some species) can be produced on artificial media, large-scale production of most pathogens has not yet been accomplished. Precise production and storage conditions must be established and maintained to ensure that infective spores are produced and stored without loss of viability before they are applied. Once applied, pathogenic fungi often are effective only if environmental conditions are favorable; high humidity or rainfall usually is important. Where fungal pathogens are incorporated in soil to control below-ground pests, the adverse effects of ultraviolet radiation and desiccation are minimized, but other microorganisms that act as competitors or antagonists often alter pathogen effectiveness.

Although no fungal pathogens are currently registered or commercially available in the United States, one or more fungi are used in Great Britain, China, the Soviet Union, and additional countries in eastern Europe and South America. Fungi used as insecticides include the following:

Beauveria bassiana: This common soil fungus has a broad host range that includes many beetles. It infects both larvae and adults of many species. One or more companies currently are developing preparations of this fungus for EPA registration; the Colorado potato beetle is a key target pest in research and development efforts. Understanding the interactions between *Beauveria bassiana* and other soil microorganisms may be the key to successful use of this fungus.

Nomuraea rileyi: In soybeans (especially in the southeastern United States), naturally occurring epidemic infections of *Nomuraea rileyi* cause dramatic reductions in populations of foliage-feeding caterpillars. Research directed at predicting disease outbreaks caused by this fungus may help in determining the need for application of insecticides.

Verticillium lecanii: This fungus (once sold under the trade name Vertelec®) has been used in greenhouses in Great Britain to control aphids and whiteflies.

Lagenidium giganteum: This aquatic fungus is highly infectious to larvae of several mosquito genera. It cycles effectively in the aquatic environment (spores produced in infected larvae persist and infect larvae of subsequent generations), even when mosquito density is low. Its effectiveness is limited by high temperatures.

Hirsutella thompsonii: Although preparations of this pathogen were once registered by the US EPA and marketed under the trade name Mycar®, it is no longer available commercially. *Hirsutella thompsonii* is a pathogen of the citrus rust mite.

PROTOZOA

Protozoan pathogens naturally infect a wide range of insect hosts. Although these pathogens can kill their insect hosts, many are more important for their chronic, debilitating effects. One important and common consequence of protozoan infection is a reduction in the number of offspring produced by infected insects. Although protozoan pathogens play a significant role in the natural limitation of insect populations, few appear to be suited for development as insecticides.

Species in the genera *Nosema* and *Vairimorpha* seem to offer the greatest potential for use as insecticides. Pathogens in these genera attack Lepidopteran larvae and insects in the order Orthoptera (the grasshoppers and related insects). The one protozoan currently available in a registered insecticidal formulation is the microsporidian *Nosema locustae*, a pathogen of grasshoppers. It is sold under such trade names as NOLO Bait® and Grasshopper Attack®. It is most effective when ingested by immature grasshoppers (the early nymphal stages). Infections progress slowly; where the pathogen kills the grasshopper, death occurs three to six weeks after initial infection. Not all infected hoppers are killed.

Nosema locustae has been used to reduce grasshopper populations in rangeland areas, and adequate control has been achieved when treatments were applied to large areas while hoppers were still young. Although not all grasshoppers in the treated area are killed by *Nosema locustae*, infected hoppers consume less forage and infected females produce fewer viable eggs than do uninfected females. *Nosema locustae* persists on egg pods to provide varying degrees of infection the following season. The effectiveness and utilization of *Nosema locustae* for rangeland grasshopper control are likely to increase as research continues.

Unfortunately, small, one-pound packages of *Nosema locustae* preparations developed for sale to gardeners and homeowners offer much less utility (or none). The mobility of grasshoppers, coupled with the fact that infected hoppers are not killed until a few weeks after they ingest the pathogen, means that application of baits containing *Nosema locustae* to individual lawns or gardens is unlikely to reduce grasshopper densities or damage substantially. (Knowing that you infected some grasshoppers that may or may not die later in someone else's garden may be somewhat satisfying, but it doesn't help very much if your goal was to prevent damage to your vegetables.)

NEMATODES

To be accurate, nematodes are not microbial agents. Instead, they are multicellular roundworms. Nematodes used in insecticidal products are, however, nearly microscopic in size, and they are used much like the truly microbial products discussed previously. Nematodes used for insect control infect only insects or related arthropods; they are called entomogenous nematodes.

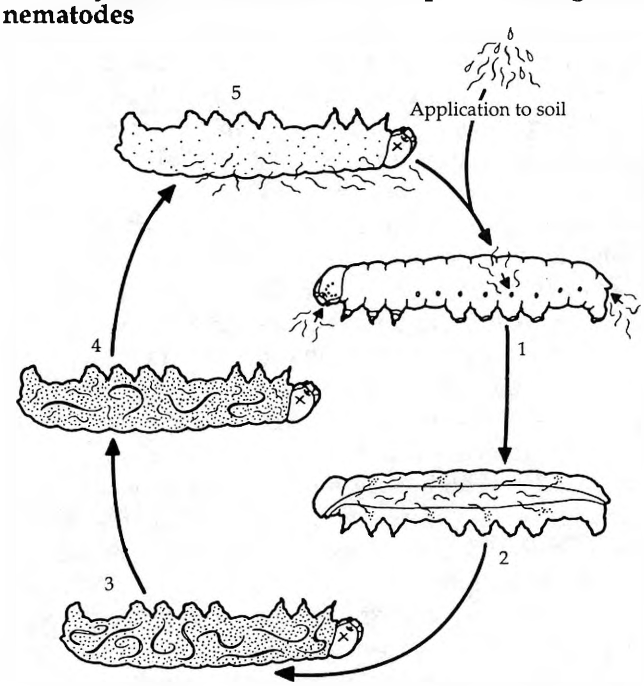
The entomogenous nematodes *Steinernema feltiae* (sometimes identified as *Neoaplectana carpocapsae*) and *Heterorhabditis heliothidis* are the species most commonly used in insecticidal preparations. Within each of these species, different strains exhibit differences in their abilities to infect and kill specific insects. In general, however, these nematodes infect a wide range of insects. On a worldwide basis, laboratory or field applications have been effective against over 400 pest species, including numerous beetles, fly larvae, and caterpillars.

The infectious stage of these nematodes is the third juvenile stage often referred to as the J3 stage or the "dauer" larva. Nematodes in this stage survive without feeding in moist soil and similar habitats, sometimes for extended periods. *Steinernema* species infect host insects by entering through body openings—the mouth, anus, and spiracles (breathing pores). *Heterorhabditis* juveniles also enter host insects through body openings, and in some instances are also able to penetrate an insect's cuticle. If the environment is warm and moist, these nematodes complete their life cycle within the infected insect. Infective juveniles molt to form adults, and these adults produce a new generation within the same host. As the offspring mature to the J3 stage, they are able to leave the dead insect and seek a new host.

Symbiotic bacteria associated with entomogenous nematodes actually cause the death of infected insects. Once inside an insect host, nematodes empty their gut bacteria into the insect's bloodstream. The nematodes then feed on these bacteria as they multiply. The insect dies from bacterial septicemia. These entomogenous nematodes and their associated bacteria (*Xenorhabdus nematophilus* and *Xenorhabdus luminescens*) have been tested extensively for toxicity to nontarget organisms, and they are considered to be nontoxic and nonpathogenic to plants and mammals.

Large-scale production of nematodes has been initiated, and a few insecticides containing entomogenous nematodes are now marketed. These products contain infective juveniles (the J3 stage) and are formulated for application as sprays or drenches. Although *Steinernema* and *Heterorhabditis* species have been shown to be effective against a great number of insect species in laboratory experiments, their host range in field applications is often limited by temperature and moisture conditions in the target insect's habitat. Although controlled desiccation has been used successfully for the formulation of some insecticidal products containing nematodes, desiccation in the field usually kills entomogenous nematodes. Consequently, nematodes are most effective when applied to control insects in moist soil, plant tissues, or other protected habitats. Their viability and persistence in soil varies greatly depending upon soil moisture and temperature and other organisms present. The following examples illustrate situations in which nematodes are likely to provide effective insect control.

Life cycle of *Steinernema* sp. entomogenous nematodes



(1) Infective juveniles enter the gut or respiratory system through body openings (mouth, anus, and breathing pores). (2) Infective juveniles actively penetrate the gut wall, enter the body cavity, and release bacteria. (3) As bacteria multiply, host dies of septicemia; juveniles feed on bacteria and host tissues and develop into adults. (4) Adults mate and reproduce; 2-3 generations are produced if conditions are adequate. (5) When the food supply is exhausted, a new generation of infective juveniles exits the host and searches for a new one.

Adapted from Woodring and Kaya (1988)

For the control of annual white grubs in grass sod, entomogenous nematodes should be effective when applied at the right time to adequately watered turf. If applications are made when grubs are present (early to late August in Illinois, with correct timing dependent upon latitude and annual variations in weather), nematodes (and synthetic insecticides) need to remain active only for a period of several days to reduce grub damage. Because most homeowners and turf managers are able to irrigate, they can effectively "water in" nematode applications and keep soils moist enough to favor nematode survival and grub infection. Although nematodes may survive for extended periods (up to several months) in cool, moist soils, homeowners should probably expect that nematodes will persist for only two to four weeks following application for grub control.

Nematodes also have been used effectively in trials against root weevil larvae and similar soil pests attacking nursery plants, ornamental plantings, garden crops, and potted plants. The ability to maintain soil moisture is an important factor in the success of these treatments.

In Midwest field crops, nematodes offer less promise for the control of major soil pests such as cutworms, corn rootworms, wireworms, and grubs. For the most part, these crops are not irrigated, and the inability to control soil moisture is a major factor limiting the success of nematode applications. Although timing applications to correspond with periods of adequate soil moisture might prove helpful, research efforts have not yet produced successful results in nonirrigated crops. For irrigated field crops, the cost of nematode products will also be an important factor that will determine whether or not large-scale use can be practical and economical.

Nematodes are not appropriate for termite control. Entomogenous nematodes are infectious to termites, but they are not likely to provide the long-term persistence needed in a termiticide. In soils around and under buildings, low moisture levels and the probable long-term absence of host insects would, in most cases, prevent nematode survival (persistence). Consequently, the need for long-term control would require repeated applications of nematodes at intervals not yet determined. Because repeated applications are impractical and undesirable, nematodes are not recommended for termite control.

Until further research provides data on specific pests, we recommend against the use of nematodes to control most above-ground insects. When nematodes can be placed in moist, protected environments where insects are confined (such as tunnels bored into tree trunks or other plant tissues), treatments can be effective. When nematodes are applied to exposed foliage or other locations where desiccation occurs rapidly, treatments are not likely to be effective.

Although commercial availability is likely to increase, nematodes are currently sold primarily by mail order from gardening supply houses (or wholesale to large-volume purchasers). Trade names include Scanmask® and BioSafe®; some products simply use the scientific name of the nematode. Nematodes are not considered by the US EPA to be pathogens, and nematode producers are not required to complete the same EPA registration process required of producers of other microbial pesticides. This exemption means reduced start-up costs for the manufacture of

MICROBIAL INSECTICIDES

A Summary of Products and Their Uses

PATHOGEN	PRODUCT NAME	HOST RANGE	USES AND COMMENTS
BACTERIA			
Bacillus thuringiensis var. *kurstaki* (*Bt*)	Bactur®, Bactospeine®, Caterpillar Killer®, Dipel®, Futura®, Javelin®, SOK®-Bt, Thuricide®, Topside®, Tribactur®, Worm Attack®	caterpillars (larvae of moths and butterflies)	Effective for foliage-feeding caterpillars (and Indian-meal moth in stored grain). Deactivated rapidly in sunlight; apply in the evening or on overcast days and direct some spray to lower sufaces of leaves. Does not cycle extensively in the environment. Available as liquid concentrates, wettable powders, and ready-to-use dusts and granules. Active only if ingested.
Bacillus thuringiensis var. *israelensis* (*Bti*)	Bactimos®, Mosquito Attack®, Skeetal®, Teknar®, Vectobac®	larvae of *Aedes* and *Psorophora* mosquitoes, black flies, and fungus gnats	Effective against larvae only. Active only if ingested. *Culex* and *Anopheles* mosquitoes are not controlled at normal application rates. Activity is reduced in highly turbid or polluted water. Does not cycle extensively in the environment. Applications generally made over wide areas by mosquito and blackfly abatement districts.
Bacillus thuringiensis var. *san diego*	M-One®	larvae of Colorado potato beetle, elm leaf beetle adults	Effective against Colorado potato beetle larvae and the elm leaf beetle. Like other *Bts*, it must be ingested. It is subject to breakdown in ultraviolet light and does not cycle extensively in the environment.
Bacillus thuringiensis var. *tenebrionis*	Trident®	larvae of Colorado potato beetle	Registration pending. Very similar to *Bacillus thuringiensis* var. *san diego* (M-One).
Bacillus thuringiensis var. *aizawai*	Certan®	wax moth caterpillars	Used only for control of wax moth infestations in honeybee hives.
Bacillus popilliae and *Bacillus lentimorbus*	Doom®, Japidemic®, Milky Spore Disease, Grub Attack®	larvae (grubs) of Japanese beetle	The main Illinois lawn grub (the annual white grub, *Cyclocephala* sp.) is NOT susceptible to milky spore disease. The disease is very effective against Japanese beetle grubs (not a major pest in Illinois) and cycles effectively for years in the soil.
Bacillus sphaericus	(in development)	larvae of *Culex*, *Psorophora*, and *Culiseta* mosquitoes, larvae of some *Aedes* spp.	Not registered or available commercially as of 1989. Active only if ingested. Under development for use against *Culex*, *Psorophora*, and *Culiseta* species; also effective against *Aedes vexans*. Remains effective in stagnant or turbid water. Commercial formulations will not cycle to infect subsequent generations.
FUNGI			
Beauveria bassiana	(in development)	many soil-dwelling insects	Not registered or available commercially as of 1989. Under development for control of Colorado potato beetle and several other beetle pests. High moisture requirements, lack of storage longevity, and competition with other soil microorganisms are problems that remain to be solved.

MICROBIAL INSECTICIDES

A Summary of Products and Their Uses (continued)

PATHOGEN	PRODUCT NAME	HOST RANGE	USES AND COMMENTS
FUNGI *(continued)*			
Lagenidium giganteum	(in development)	larvae of most pest mosquito species	Not registered or available commercially as of 1989. Effective against larvae of most pest mosquito species; remains infective in the environment through dry periods. A main drawback is its inability to survive high summertime temperatures.
PROTOZOA			
Nosema locustae	NOLO® Bait, Grasshopper Attack®	grasshoppers and mormon crickets	Useful for rangeland grasshopper control. Active only if ingested. Not recommended for use on a small scale, such as backyard gardens, because the disease is slow acting and grasshoppers are very mobile.
VIRUSES			
Gypsy moth nuclear polyhedrosis (NPV)	Gypchek® virus	gypsy moth caterpillars	All of the viral insecticides used for control of forest pests are produced and used exclusively by the U.S. Forest Service.
Tussock moth NPV	TM Biocontrol-1®	tussock moth caterpillars	
Pine sawfly NPV	Neochek-S®	pine sawfly larvae	
Coddling moth granulosis virus (GV)	(see comments)	codling moth caterpillars	Commercially produced and marketed briefly, but no longer registered or available. Future re-registration is possible. Active only if ingested. Subject to rapid breakdown in ultraviolet light.
ENTOMOGENOUS NEMATODES			
Steinernema feltiae (=*Neoaplectana carpocapsae*) and other *Steinernema* species	Biosafe®, Scanmask®, also sold generically (wholesale and retail)	larvae of a wide variety of soil-dwelling and boring insects	*Steinernema feltiae* is the main nematode species marketed retail in the U.S. Because of moisture requirements, it is effective primarily against insects in moist soils or inside plant tissues. Prolonged storage or extreme temperatures before use may kill or debilitate the nematodes. Effective in cool temperatures.
Heterorhabditis heliothidis	currently available on a wholesale basis for large-scale operations	larvae of a wide variety of soil-dwelling and boring insects	Not commonly available by retail in the U.S.; this species is used more extensively in Europe. Available by wholesale or special order for research or large-scale commercial uses. Similar in use to *Steinernema* species but with some differences in host range, infectivity, and temperature requirements.

products containing entomogenous nematodes, but it also means less standardization and less outside regulation of quality. As major producers of entomogenous nematodes gain a reputation for marketing high-quality products, consumers can expect these companies to practice effective quality control. Nonetheless, in the absence of extensive regulation, some suppliers are likely to market inferior products accompanied by exaggerated claims. Because of differences among nematode products and lack of regulation, buyers are urged to be careful consumers. These products offer a great deal of potential, but their efficacy is not as unlimited as some promotions suggest.

SUMMARY

Microbial insecticides offer effective alternatives for the control of many insect pests. Their greatest strength is their safety, as they are essentially nontoxic and nonpathogenic to animals and humans. Although not every pest problem can be controlled by the use of a microbial insecticide, these products can be used successfully in place of more toxic insecticides to control many lawn and garden pests and several important field crop and forest insects. Because most microbial insecticides are effective against only a narrow range of pests and because these insecticides are vulnerable to rapid inactivation in the environment, users must properly identify target pests and plan the most effective application. But these same qualities mean that microbial insecticides can be used without undue risks of human injury or environmental damage. Consequently, microbial insecticides are likely to become increasingly important tools in insect management.

ACKNOWLEDGMENT

The following reviewers contributed to this publication: Brian Melin, Abbott Laboratories; Richard Miller, BioSys; Tom Quick, Mycogen; Tom Sluss, Evans Biocontrol; Joseph Maddox, Robert Novak, Audrey Hodgins, and Lorin Nevling, Illinois Natural History Survey; Kevin Steffey and Phil Nixon, Cooperative Extension Service, University of Illinois.

Funding to develop this publication was provided in part by a grant from the Illinois Department of Energy and Natural Resources (ENR Proj. No. IP13) and by the Cooperative Extension Service, University of Illinois.

SELECTED REFERENCES

Ferron, P. 1978. Biological control of insect pests by entomogenous fungi. Ann Rev Entomol 23: 409-442.

Fuxa, J.R. 1987. Ecological considerations for the use of entomopathogens in IPM. Ann Rev Entomol 32: 225-251.

Harper, J.D. 1987. Present and future status of microbial control of arthropods. Crop Protection 6(2): 117-122.

Lacey, L.A., and A.H. Undeen. 1986. Microbial control of black flies and mosquitoes. Ann Rev Entomol 31: 265-296.

Kurstak, E. (editor). 1982. Microbial and Viral Pesticides. Marcel Dekker, New York. (Contains useful chapters on bacterial, viral, and fungal pathogens)

*McCoy, C.W. (editor). 1987. Microbial Agents for Use in Integrated Pest Management Systems. Southern Cooperative Series Bulletin 318. Southern Regional Project S-135: Entomopathogens for Use in Pest-Management Systems. Arkansas Agricultural Experiment Station, Fayetteville. 32 pp.

*Woodring, J.L., and H.K. Kaya. 1988. Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques. Southern Cooperative Series Bulletin 331. Southern Regional Project S-135: Entomopathogens for Use in Pest-Management Systems. Arkansas Agricultural Experiment Station, Fayetteville. 30 pp.

*Requests for these publications may be sent to 110 Agricultural Building, University of Arkansas, Fayetteville, AR, 72701.

Botanical Insecticides and Insecticidal Soaps

Synthetic insecticides have played an important and beneficial role in the control of agricultural pests and the reduction of insect-borne diseases for more than forty years. Over time, however, certain risks and drawbacks associated with the use of synthetic insecticides have become increasingly apparent. Some synthetic insecticides leave undesirable residues in food, water, and the environment. Low doses of many insecticides are toxic to humans and other animals, and some insecticides are suspected carcinogens. As a result, many researchers, farmers, and homeowners are seeking less hazardous alternatives to conventional synthetic insecticides.

The ideal insecticide should control target pests adequately and should be target-specific (able to kill the pest insect but not other insects or animals), rapidly degradable, and low in toxicity to humans and other mammals. Two classes of insecticides that exhibit some of these characteristics are the botanical insecticides and the insecticidal soaps. Botanical insecticides, sometimes referred to as "botanicals," are naturally occurring insecticides derived from plants. Insecticidal soaps are soaps that have been selected and formulated for their insecticidal action.

Botanical insecticides and insecticidal soaps are promising alternatives for use in insect management. However, like conventional synthetic insecticides, botanicals and insecticidal soaps have advantages and disadvantages and should be judged accordingly. Each compound must be evaluated in terms of its toxicity, effectiveness, environmental impacts, and costs.

The strengths and weaknesses of botanical insecticides and insecticidal soaps are briefly summarized in this circular. Each compound is discussed in terms of its mode of action, mammalian toxicity, and practical uses. General information on the history and development of botanicals, insecticide toxicology, and state registration requirements is also presented. Insecticide toxicity is stressed throughout this circular. Even though botanicals and insecticidal soaps are naturally derived and are relatively safe to use if used properly, they are poisons and should be handled with the same caution as synthetic insecticides.

Advantages of Botanical Insecticides and Insecticidal Soaps

Many compounds with diverse chemical structures and different modes of action are classified as botanical insecticides or insecticidal soaps. It is therefore difficult to present a detailed list of advantages or disadvantages that apply to all of the compounds included in this category. Some general advantages shared by most of these compounds are:

- **Rapid degradation.** Botanicals and insecticidal soaps degrade rapidly in sunlight, air, and moisture and are readily broken down by detoxification enzymes. This is very important because rapid breakdown means less persistence in the environment and reduced risks to nontarget organisms. Soaps and many botanicals may be applied to food crops shortly before harvest without leaving excessive residues.

- **Rapid action.** Botanicals and soaps act very quickly to stop feeding by pest insects. Although they may not cause death for hours or days, they often cause immediate paralysis or cessation of feeding.

- **Low mammalian toxicity.** Most botanicals and insecticidal soaps have low to moderate mammalian toxicity. There are exceptions, however; see section "The Toxicity of Insecticides" for a general discussion of insecticide toxicities.

NOTE: The information in this circular is provided for educational purposes only. Trade names of insecticides have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Prepared by Tess Henn and Rick Weinzierl, Office of Agricultural Entomology,
University of Illinois at Urbana-Champaign,
College of Agriculture, Cooperative Extension Service,
in cooperation with the Illinois Natural History Survey

Circular 1296
September 1989

- **Selectivity.** Although most botanicals have broad spectrum activity in standard laboratory tests, in the field their rapid degradation and their action as stomach poisons make them more selective in some instances for plant-feeding pest insects and less harmful to beneficial insects.

- **Low toxicity to plants.** Most botanicals are not phytotoxic (toxic to plants). Insecticidal soaps and nicotine sulfate, however, may be toxic to some ornamentals.

Disadvantages of Botanical Insecticides and Insecticidal Soaps

The following disadvantages do not preclude the effective use of botanicals or insecticidal soaps, but do call attention to certain factors that must be considered when using these insecticides.

- **Rapid degradation.** Rapid breakdown of botanicals, although desirable from an environmental and human health standpoint, creates a need for more precise timing and/or more frequent insecticide applications.

- **Toxicity.** Although the insecticidal soaps and most botanicals are the lesser of many "evils" in terms of general pesticide toxicities, they are toxins nonetheless. All toxins used in pest control pose some hazard to the user and to the environment. In addition, toxins are useful only when incorporated into a conscientious program of pest management that includes sanitation, cultural control, crop rotation, and use of resistant plant varieties. No insecticides, natural or synthetic, should be used as the sole means of defense against pest insects.

- **Cost and availability.** Botanicals tend to be more expensive than synthetics, and some are not as widely available. In addition to problems of supply, the potency of some botanicals may differ from one source or batch to the next.

- **Lack of test data.** Data on effectiveness and long-term (chronic) toxicity are unavailable for some botanicals. Tolerances for residues of some botanicals on food crops have not been established.

- **State registration.** Several botanicals are registered by the United States Environmental Protection Agency (US EPA) and are available by mail order, but are not registered for legal sale in Illinois. (See section "The Registration of Botanical Insecticides in Illinois" for more on this problem.)

What Are Botanical Insecticides and Insecticidal Soaps?

Botanicals are naturally occurring insecticides derived from plant sources. They are processed into various forms.

- **Preparations of the crude plant material.** These are dusts or powders made from ground dried plant parts that have not been extracted or treated extensively. They are marketed either full strength or diluted with carriers such as clays, talc, or diatomaceous earth. Examples include dusts or wettable powders of cubé roots (rotenone), pyrethrum flowers, sabadilla seeds, ryania stems, or neem leaves, fruits, or bark.

- **Plant extracts or resins.** These are water or solvent extracts that concentrate the insecticidal components. Such extracts or resins are formulated into liquid concentrates or are impregnated onto dusts or wettable powders. Botanicals in this form include pyrethrins, cubé resins (rotenone), citronella and other essential oils, and neem seed extracts or oils.

- **Pure chemicals isolated from plants.** These are purified insecticidal compounds that are isolated and refined by a series of extractions, distillations, or other processes and are formulated into concentrates. Included in this category are nicotine, d-limonene, and linalool.

Insecticidal soaps are specially formulated soaps that contain the potassium or sodium salts of insecticidal fatty acids. **Safer®** soaps, the most widely marketed insecticidal soaps, contain the potassium salt of oleic acid, a fatty acid found in certain vegetable oils.

Crude botanical insecticides have been used for centuries and were known in tribal or traditional cultures long before being introduced into Europe or the United States. Botanicals with long histories of traditional use include neem in India, rotenone in East Asia and South America, and pyrethrum in Persia (Iran).

From the late 1800s to the 1940s, botanicals and insecticidal soaps were used extensively on certain crops. Soaps and nicotine-based insecticides were important before the turn of the century, while pyrethrum, rotenone, sabadilla, and ryania were popular in the 1930s and early 1940s. During that time, research on botanicals focused on efficacy, development of new formulations, and the use of synergists (compounds that enhance insecticidal action). With the development of synthetic insecticides in the mid-1940s, the use of botanicals was largely abandoned in commercial agriculture; the new synthetic compounds were less expensive, more effective, and longer lasting.

From 1945 to the early 1970s, the only botanicals remaining in wide use were pyrethrins (used as household and industrial sprays and aerosols) and nicotine (used in greenhouses and orchards). Home gardeners continued to use rotenone on a small scale. Use of sabadilla and ryania was virtually abandoned, and for years these compounds were unavailable in the U.S.

In the past ten or fifteen years, interest in botanicals has increased, primarily as a result of concerns about environmental contamination and pesticide residues in foods. In a few instances, botanical insecticides have come into commercial use because a key pest has become resistant to most classes of synthetic insecticides, e.g., the use of rotenone for control of the Colorado potato beetle on Long Island in New York.

Botanicals and insecticidal soaps are not widely used in conventional commercial agriculture, but small-scale organic growers and home gardeners are using them more extensively. In addition, many new state certification programs for organic farming allow the use of insecticidal soaps and most botanical insecticides. As a result, botanical insecticides that for years were unavailable have been reregistered and are being produced and marketed in limited quantities. Several new botanical insecticides, such as the citrus oil derivatives and new formulations of neem also are available or are under development.

Synergists. Insects, like humans and other animals, possess enzymes that are capable of breaking down a wide variety of toxic substances. Certain natural insecticides—pyrethrins in particular, as well as several other botanicals—are readily attacked and degraded by these enzymes once inside the insect's system. In some cases, degradation occurs so rapidly that the insecticide is not active long enough to kill the insect. The insect is temporarily stunned, but then recovers.

Synergists are compounds that enhance insecticidal action by inhibiting certain detoxification enzymes. The synergists used in commercial insecticides block a system of enzymes known as the multifunction oxidases (MFOs); consequently, these synergists increase the effective toxicity of those insecticides that are easily degraded by the MFOs. Insecticides that are not readily detoxified by the MFOs are not synergized by these compounds. The synergists themselves are low in toxicity, have little or no inherent insecticidal properties, and have very short residual activity.

The most commonly used synergist is piperonyl butoxide (PBO). PBO is found in most products that contain pyrethrins. It is also an effective synergist for rotenone, sabadilla, ryania, and the citrus oil derivatives, as well as some synthetic pyrethroids and carbamate insecticides. MGK 264 (N-octyl bicycloheptene dicarboximide) is another synergist that is sometimes used in livestock and animal shelter insecticides. Both of these compounds have low mammalian toxicity (see Table 1). They are usually formulated with insecticides in ratios of from 2:1 to 10:1 (synergist: insecticide). High cost is the major factor limiting more widespread use of synergists. In addition, some organic certification programs do not allow the use of PBO.

THE BOTANICAL INSECTICIDES

(A general discussion of insecticide toxicity and a table of LD_{50} values are presented in "The Toxicity of Insecticides." Refer to those pages and to the section "Terms to Understand" for further explanations of the toxicological information presented in this section.)

Pyrethrum and Pyrethrins

Source. Pyrethrum is the powdered, dried flower head of the pyrethrum daisy, *Chrysanthemum cinerariaefolium*. Most of the world's pyrethrum crop is grown in Kenya. The term "pyreth*rum*" is the name for the crude flower dust itself, and the term "pyreth*rins*" refers to the six related insecticidal compounds that occur naturally in the crude material. The pyrethrins constitute 0.9-1.3% of dried pyrethrum flowers. They are extracted from crude pyrethrum dust as a resin that is used in the manufacture of various insecticidal products.

THE TOXICITY OF INSECTICIDES

Although many household and industrial products, including cleaning and polishing agents, degreasers, paints, and solvents, are toxic, insecticides are among only a few compounds used intentionally as poisons. The nature of insecticide toxicity and the manner in which insecticides are applied can make these compounds particularly hazardous. Because of this, it is important that insecticide users understand the basics of insecticide toxicology.

Insecticides are, by definition, compounds intended to kill insects. Most insecticides attack basic physiological processes such as nerve transmission or cellular respiration, processes that are common to insects, humans, and other animals. Whether natural or synthetic in origin, most insecticides can poison many forms of animal life. The risk of accidental poisoning may be heightened if a pesticide user perceives an insecticide to be harmless and consequently overapplies or misuses it. Such a problem can result from the widely held misconception that naturally derived insecticides are basically nontoxic to humans and other animals and are therefore "safe" to use in a careless manner. While most botanicals pose fewer hazards than many synthetic insecticides, their toxicity is still a factor to be considered.

Insecticide toxicity. The toxicity of any chemical is usually evaluated in terms of both acute and chronic effects. Acute toxicity refers to the effects of a single dosage or exposure. Chronic toxicity refers to the effects of repeated doses or exposures over time.

The acute toxicity of an insecticide is generally described in terms of an LD_{50}, the dose required to kill 50 percent of the animals in a test. An LD_{50} is therefore a "median lethal dose." LD_{50} values are usually expressed as milligrams of toxicant per kilogram of body weight of a test animal (mg/kg). Consequently, **a lower LD_{50} indicates a more toxic compound.** For example, an insecticide with an LD_{50} of 60 mg/kg is much more toxic than one with an LD_{50} of 5,000 mg/kg.

The most common measures of an insecticide's toxicity to mammals are its oral and dermal LD_{50} values. Testing is generally performed on laboratory animals such as mice, rats, guinea pigs, or rabbits. Test animals are exposed to a range of single doses—a certain number of animals at each dose—to determine the insecticide's acute oral or dermal toxic effects. Estimates of an insecticide's acute human toxicity are derived from this type of animal testing.

While LD_{50} values are useful indicators of toxicity, they do not provide a full picture of all of the risks associated with insecticide contact. For example, LD_{50} values fail to indicate toxic effects other than death. These effects may include eye injury, throat and lung irritation, chemical burns, neurolgical damage and many other forms of injury. In addition, LD_{50} values generally indicate the acute toxicity of pure, unformulated insecticidal compounds rather than the diluted, formulated products actually used by consumers. Formulation (the process of turning a pure active ingredient into a finished insecticidal product) usually reduces poisoning risks because it involves diluting the active compounds with various carriers and additives. In some instances, however, formulation may increase poisoning risks; this occurs when carriers or other ingredients include toxic solvents or solvents that speed the entry of the active compounds into the body.

In comparison with questions about acute toxicity, questions about the chronic effects of repeated exposures to lower doses of pesticides are much more difficult to answer clearly. To investigate chronic effects, a compound is administered to laboratory animals at a range of doses (usually including the maximum dose that the animal can survive) for an extended period of time. The most common means of administering compounds is in combination with the animal's food, but compounds are sometimes administered dermally or by injection or inhalation. Following chronic exposures over a normal life span, the test animals are killed and examined for tumor production and other changes in major tissues and organs. A key purpose for chronic toxicity testing is to identify probable carcinogens (cancer-causing agents). Investigations of reproductive effects (birth rate, birth weight, incidence of birth defects) might also be conducted during each study.

Acute and chronic toxicity tests give indications of the immediate and long-term effects of human exposure to pesticides, but it is important to recognize that such tests provide only limited information. For instance, because different species react to insecticides in different ways, tests that measure rodent responses may not always accurately predict human responses. In addition, single-compound tests do not measure the effects of real-life human exposures to multiple compounds. Chronic, high-dose tests used to identify possible carcinogens may or may not yield results that are relevant for the prediction of cancer risks associated with the infrequent, low-level exposures that most humans are expected to encounter. Yet despite these limitations, toxicological testing has produced results that help to describe the risks associated with pesticide exposure and that allow some meaningful comparisons of synthetic and botanical insecticides.

Botanicals versus synthetics. It is important to understand that natural compounds are not inherently less toxic to humans than synthetic ones. Some of the most deadly, fast-acting toxins and some potent carcinogens occur naturally. **Despite the claims presented in some advertising materials, "natural" does not necessarily mean safe or nontoxic, and it certainly does not mean non-chemical.**

The LD_{50} values presented in Table 1 illustrate the fact that botanical insecticides range from practically nontoxic (such as neem or Safer® soap) to very toxic (such as nicotine). Most are only slightly to moderately toxic. LD_{50} values for some common organophosphate, carbamate, and pyrethroid insecticides are also listed in Table 1 for comparison.

In evaluating the toxicities listed in Table 1, it is important to consider the situations that might lead to pesticide exposures and poisoning. Human exposure to pesticides usually results from careless contact during application or from contacting or eating residues that remain on treated materials or foods. Because botanical insecticides and insecticidal soaps break down rapidly in the environment, they rarely pose any risk to consumers concerned about harmful residues on foods or other materials. Many synthetic insecticides are much more stable, and problems associated with persistent residues present a more realistic concern. As a result, where a short-lived insecticide (a botanical, a soap, or certain synthetics such as resmethrin) and a more persistent insecticide (certain synthetics such as permethrin or chlorpyrifos) are characterized by similar LD_{50} values, the persistent product is much more likely to pose some risk to persons other than the applicator.

For applicators, however, certain botanical insecticides and synthetic insecticides can pose very similar risks. Rotenone and ryania, for example, are similar to carbaryl and malathion in acute toxicity; applicators may be poisoned by careless exposure to any of these products. The important concept to remember is that although the environmental safety of all botanical insecticides is enhanced by their rapid degradation, several botanical insecticides can readily poison the careless applicator. Users should always wear protective clothing and avoid insecticide exposure.

Table 1

Botanical Insecticides and Insecticidal Soaps

A Summary of the Toxicity of Various Insecticides

GENERIC NAME (TRADE NAME)	CLASS	ORAL LD_{50}	DERMAL LD_{50}	SIGNAL WORD**
Insecticidal soap (Safer®)	Soap	16,500	--	caution
Neem	Botanical	13,000	--	N/A
Piperonyl butoxide (PBO)	Synergist	>7,500	7,500	caution
d-Limonene (VIP®)	Botanical	>5,000	--	caution
Sabadilla (Red Devil®)	Botanical	4,000	--	caution
MGK 264	Synergist	2,800	--	caution
Resmethrin	Pyrethroid	>2,500	3,000	caution
Linalool (Demize®)	Botanical	2,440-3,180	3,578-8,374	caution
Pyrethrins	Botanical	1,200-1,500	>1,800	caution
Malathion	Organophosphate	885-2,800	4,100	caution
Carbaryl (Sevin®)	Carbamate	850	>4,000	warning/ caution
Ryania (Ryan 50®)	Botanical	750-1,200	4,000	caution
Permethrin (Pounce®, Ambush®)	Pyrethroid	430-4,000*	>2,000	danger/ warning
Chlorpyrifos (Lorsban®)	Organophosphate	135-163	2,000	warning/ caution
Rotenone	Botanical	60-1,500*	940-3,000	caution
Nicotine (Black-Leaf 40®)	Botanical	50-60	50	danger
Carbofuran (Furadan®)	Carbamate	8-14	>2,500	danger/ warning
Terbufos (Counter®)	Organophosphate	2-5	7	danger

* Toxicity varies greatly depending on type of solvent used as a carrier
** See Table 2.

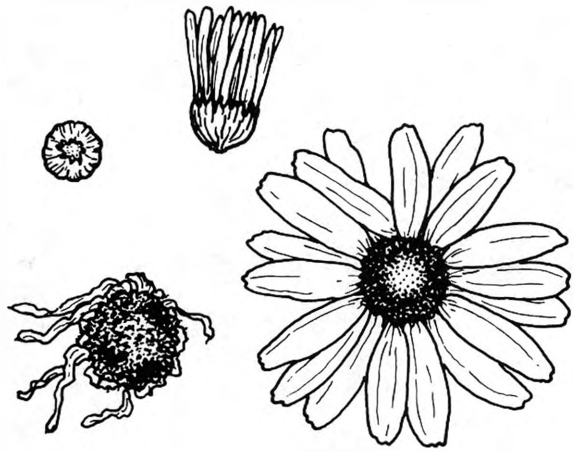


Figure 1. Stages of the pyrethrum daisy, the source of natural pyrethrins.

Mode of action. Pyrethrins exert their toxic effects by disrupting the sodium and potassium ion exchange process in insect nerve fibers and interrupting the normal transmission of nerve impulses. Pyrethrins insecticides are extremely fast acting and cause an immediate "knockdown" paralysis in insects. Despite their rapid toxic action, however, many insects are able to metabolize (break down) pyrethrins quickly. After a brief period of paralysis, these insects may recover rather than die. To prevent insects from metabolizing pyrethrins and recovering from poisoning, most products containing pyrethrins also contain the synergist PBO. Without PBO the effectiveness of pyrethrins is greatly reduced.

Mammalian toxicity. Pyrethrins are low in mammalian toxicity (see Table 1), and few cases of human poisonings have ever been reported. Cats, however, are highly susceptible to poisoning by pyrethrins, and care must be taken to follow label directions closely when using products containing pyrethrins to treat cats for fleas.

When ingested, pyrethrins are not readily absorbed from the digestive tract, and they are rapidly hydrolyzed under the acid conditions of the gut and the alkaline conditions of the liver. Pyrethrins are more toxic to mammals by inhalation than by ingestion because inhalation provides a more direct route to the bloodstream. Exposure to high doses may cause nausea, vomiting, diarrhea, headaches, and other nervous disturbances. Repeated contact with crude pyrethrum dusts may cause skin irritation or allergic reactions. The allergens that cause these reactions are not present in products containing refined pyrethrins. Tests indicate that chronic exposure to pyrethrins does not cause genetic mutations or birth defects (see Casida, 1973, and Hayes, 1982).

There is no single antidote for acute pyrethrin poisoning. Treatment of poisoning is symptomatic, i.e., the various symptoms of poisoning are treated individually as they occur because there is no way to counteract the source of the poisoning directly.

Uses: Pyrethrins are contact poisons that have almost no residual activity. They break down very rapidly in sunlight, air, and moisture. Degradation is accelerated under acid or alkaline conditions, and for this reason pyrethrins should not be mixed with lime or soap solutions for application. Formulated products containing pyrethrins are stable in storage for long periods if not diluted, but powders made directly from ground pyrethrum flowers may lose up to 20% of their potency in a single year. Synergism by PBO is essential for obtaining full effectiveness from pyrethrins.

Pyrethrins are used against a broad range of pests. Products containing synergized pyrethrins (pyrethrins plus PBO) are registered for use on pets and livestock to control fleas, flies, and mosquitoes. They are also registered as indoor household sprays, aerosols, and "bombs" for the control of various flying insects, fleas, and (less effectively) ants and roaches. Formulations containing microencapsulated pyrethrins may provide some residual activity for indoor use. Synergized pyrethrins are used in food processing plants and food warehouses to give some control of stored-product pests (flour beetles, Indianmeal moth, etc.). Pyrethrins are also formulated with rotenone and ryania or copper for general use in gardens; rotenone and ryania are slower-acting compounds to which pyrethrins are added for their rapid knockdown effect.

Pyrethroid insecticides. Pyrethroids are not botanical insecticides. They are synthetic compounds that are based on the chemical structure and physiological action of the natural pyrethrins, but they are more toxic to insects and generally more persistent in the environment. A few pyrethroids, such as resmethrin (used for household insect control), are very low in mammalian toxicity and degrade quickly. Others, such as cypermethrin (used on cotton, vegetables, and fruits), are moderately toxic and highly persistent. For many of the pyrethroids, acute toxicity and hazard vary greatly depending on the kind of solvent that is used as a carrier for the formulated product. Pyrethroids are generally effective at very low concentrations and are used at much lower application rates than most other synthetic insecticides.

Rotenone

Source. Rotenone is an insecticidal compound that occurs in the roots of *Lonchocarpus* species in South America, *Derris* species in Asia, and several other related tropical legumes. Commercial rotenone was at one time produced from Malaysian *Derris*. Currently the main commercial source of rotenone is Peruvian *Lonchocarpus*, which often is referred to as cubé root.

Rotenone is extracted from cube roots in acetone or ether. Extraction produces a 2-40% rotenone resin which contains several related but less insecticidal compounds known as rotenoids. The resin is used to make liquid concentrates or to impregnate inert dusts or other carriers. Most rotenone products are made from the complex resin rather than from purified rotenone itself. Alternatively, cubé roots may be dried, powdered, and mixed directly with an inert carrier to form an insecticidal dust.

Mode of action. Rotenone is a powerful inhibitor of cellular respiration, the process that converts nutrient compounds into energy at the cellular level. In insects rotenone exerts its toxic effects primarily on nerve and muscle cells, causing rapid cessation of feeding. Death occurs several hours to a few days after exposure. Rotenone is extremely toxic to fish, and is often used as a fish poison (piscicide) in water management programs. It is effectively synergized by PBO or MGK 264.

Mammalian toxicity. Although rotenone is a potent cell toxin, mammals detoxify ingested rotenone efficiently via liver enzymes. As with pyrethrins, rotenone is more toxic by inhalation than by ingestion. Exposure to high doses may cause nausea, vomiting, muscle tremors, and rapid breathing. Very high doses may cause convulsions followed by death from respiratory paralysis and circulatory collapse. Direct contact with rotenone may be irritating to skin and mucous membranes. Treatment of poisoning is symptomatic.

Chronic exposure to rotenone may lead to liver and kidney damage. Although some rodent testing has shown that chronic dietary exposure to rotenone may induce tumor formation, the most recent US EPA registration standard considers rotenone to be noncarcinogenic (see Hayes, 1982, and the US EPA report, 1988).

Rotenone is one of the more acutely toxic botanicals. As a matter of comparison, pure, unformulated rotenone is more toxic than pure carbaryl (Sevin) or malathion, two commonly used synthetic insecticides (see Table 1). In the form of a 1% dust, rotenone poses roughly the same acute hazard as the commonly available 5% Sevin dust.

Uses. Rotenone is a broad-spectrum contact and stomach poison that is particularly effective against leaf-feeding beetles and certain caterpillar pests. On a commercial level, rotenone has been used widely in the northeastern United States to control populations of the Colorado potato beetle that have become resistant to most other registered insecticides. Rotenone is also used extensively in fish management programs.

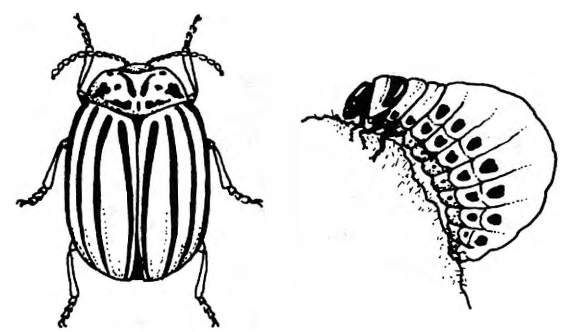


Figure 2. Colorado potato beetle, adult and larva. Rotenone is used on a commercial scale to control this major pest. In some areas of the U.S., the Colorado potato beetle has become resistant to most classes of synthetic chemical insecticides.

Several products containing rotenone in combination with pyrethrins, ryania, copper, and/or sulfur are registered for general garden and orchard insect and disease control. Rotenone is also commonly sold as a 1% dust or a 5% powder (for spraying).

Rotenone degrades (oxidizes) quickly in air and sunlight; under warm, sunny conditions dust or spray residues on exposed plant surfaces provide some degree of protection for approximately one week. Degradation is greatly accelerated by mixing rotenone with alkaline materials such as soaps or lime.

Sabadilla

Source. Sabadilla is derived from the ripe seeds of *Schoenocaulon officinale*, a tropical lily plant which grows in Central and South America. Sabadilla is also sometimes known as cevadilla or caustic barley.

When sabadilla seeds are aged, heated, or treated with alkali, several insecticidal alkaloids are formed or activated. Alkaloids are physiologically active compounds that occur naturally in many plants. In chemical terms they are a heterogeneous class of cyclic compounds that contain nitrogen in their ring structures. Caffeine, nicotine, cocaine, quinine, and strychnine are some of the more familiar alkaloids. The alkaloids in sabadilla are known collectively as veratrine or as the veratrine alkaloids. They constitute 3-6% of aged, ripe sabadilla seeds. Of these alkaloids, cevadine and veratridine are the most active insecticidally.

European white hellebore (*Veratrum album*) also contains veratridine in its roots. Hellebore was once commonly used in Europe and the U.S. for insect control, but is now unavailable commercially and is not registered by the US EPA.

Mode of action. In insects, sabadilla's toxic alkaloids affect nerve cell membrane action, causing loss of nerve function, paralysis and death. Sabadilla kills insects of some species immediately, while others may survive in a state of paralysis for several days before dying. Sabadilla is effectively synergized by PBO or MGK 264.

Mammalian toxicity. Sabadilla, in the form of dusts made from ground seeds, is the least toxic of the registered botanicals (see Table 1). Purified veratrine alkaloids are quite toxic, however, and are considered on a par with the most toxic synthetic insecticides. Sabadilla can be severely irritating to skin and mucous membranes, and has a powerful sneeze-inducing effect when inhaled. Ingestion of small amounts may cause headaches, severe nausea, vomiting, diarrhea, cramps and reduced circulation. Ingestion of very high doses may cause convulsions, cardiac paralysis, and respiratory failure. Sabadilla alkaloids can be absorbed through the skin or mucous membranes.

Uses. Sabadilla is mainly a broad spectrum contact poison, but it also has some activity as a stomach poison. It is effective against certain "true bug" pests (Order Hemiptera) such as harlequin bugs and squash bugs that are difficult to control with most other insecticides. Sabadilla is also highly toxic to honey bees, and care must be taken to avoid applying it when bees are present. The active alkaloids degrade rapidly in air and sunlight, and have little residual toxicity.

Sabadilla is registered by the US EPA for use on squash, beans, cucumbers, melons, potatoes, turnips, mustard, collards, cabbage, broccoli, citrus, and peanuts. In citrus, sabadilla is applied with sugar as an insecticidal bait (stomach poison) for citrus thrips. For vegetable insect control, sabadilla is commonly applied as a contact insecticide in the form of a 20% dust or spray. *Several sabadilla products available for purchase are not registered in Illinois. See section "The Registration of Botanical Insecticides in Illinois" for more information on this problem.*

Ryania

Source. Ryania comes from the woody stems of *Ryania speciosa*, a South American shrub. Powdered *Ryania* stem wood is combined with carriers to produce a dust or is extracted to produce a liquid concentrate. The most active compound in ryania is the alkaloid ryanodine, which constitutes approximately 0.2% of the dry weight of stem wood.

Mode of action. Ryania is a slow-acting stomach poison. Although it does not produce rapid knockdown paralysis, it does cause insects to stop feeding soon after ingesting it. Little has been published concerning its exact mode of action in insect systems. Ryania is effectively synergized by PBO and is reported to be most effective in hot weather.

Mammalian toxicity. Ryania is moderately toxic to mammals by ingestion and only slightly toxic by dermal exposure. Ingestion of large doses causes weakness, deep and slow respiration, vomiting, diarrhea, and tremors, sometimes followed by convulsions, coma, and death. Purified ryanodine is approximately 700 times more toxic than the crude ground or powdered wood and causes poisoning symptoms similar to those of synthetic organophosphate insecticides. (Depending on exposure, organophosphate poisoning symptoms may include sweating, headache, twitching, muscle cramps, mental confusion, tightness in chest, blurred vision, vomiting, evacuation of bowels and bladder, convulsions, respiratory collapse, coma, and death.)

Uses. Ryania is registered by the US EPA for use on citrus, corn, walnuts, apples, and pears for the control of citrus thrips, European corn borer, and codling moth. Ryania has longer residual activity than most other botanicals and is therefore useful where the more quickly degrading compounds are ineffective. Ryania is also sold in mixtures containing rotenone and pyrethrins for use on a variety of vegetables and fruits. *Ryania is not currently registered for sale in Illinois. See section "The Registration of Botanical Insecticides in Illinois."*

THE REGISTRATION OF BOTANICAL INSECTICIDES IN ILLINOIS

Laws governing pesticide sale and use require that any product sold to control pests must be registered (approved) by the United States Environmental Protection Agency (US EPA). In order to gain registration, the product must pass through several levels of testing for toxicity, carcinogenicity, mutagenicity, teratogenicity, environmental fate, etc. It also must be tested for safety to non-target organisms. Natural as well as synthetic insecticides must be registered by the US EPA before they may be sold and applied legally.

Under federal pesticide laws, state agencies are required to enforce the regulations that cover the safe use of EPA-registered pesticides. As a result many states, including Illinois, also require state registration before a pesticide may be sold and applied legally in that state. Registration at the state level provides both the records and the funding needed to carry out federally mandated registration enforcement. To register a pesticide in Illinois, the manufacturer must pay an annual fee of $200 for the company, plus a $50 annual fee for each individual product that is registered.

Several botanical insecticides, most notably sabadilla and ryania, are not registered in Illinois. This may result from the fact that many of the manufacturers of botanical insecticides are small companies that have limited sales. These companies have chosen not to afford the cost of registering their products with each state that requires such a step. Consequently, these unregistered botanical products cannot (or at least should not) be found on store shelves in Illinois. Instead, they are available only by mail order from various distributors of natural or alternative pest management supplies in other states.

While it is the responsibility of the manufacturers to register their products, it is the responsibility of the mail-order distributors to alert customers to the fact that certain products are not registered in the customers' home states. They should refuse to ship unregistered products into those states. Unfortunately, many mail-order distributors and manufacturers are not aware of or do not acknowledge these responsibilities. They often will ship products illegally without alerting customers to the registration laws.

Where does this leave the consumer who wishes to purchase a botanical insecticide that is not registered in Illinois? While it may seem that shipping alternative, "natural" pesticides is a harmless practice, adequate regulation of all pesticides depends upon the existence of complete records of sales and use at both the state and federal levels. Requiring registration is the only means by which a state can monitor pesticides properly. Producers of all pesticides—whether synthetic or botanical—must support state registration programs.

Perhaps the most responsible approach is for consumers to write to the Illinois Department of Agriculture (Illinois State Fairgrounds, P.O. Box 19281, Springfield, IL 62794-9281) and to the manufacturer or distributor of the specific insecticide, stating a desire to see the product registered for sale and use in Illinois. By doing so, and by refusing to order the product until it is registered, consumers can encourage the proper regulation and sale of effective, environmentally sound insecticides.

Figure 3. Nicotine is a Class I (extremely toxic) poison. By law the label on nicotine sulfate insecticides must display the signal words "DANGER POISON" along with the skull and crossbones symbol.

Nicotine

Source. Nicotine is a simple alkaloid derived from tobacco, *Nicotiana tabacum*, and other *Nicotiana* species. Nicotine contitutes 2-8% of dried tobacco leaves. Insecticidal formulations generally contain nicotine in the form of 40% nicotine sulfate and are currently imported in small quantities from India.

Mode of action. In both insects and mammals, nicotine is an extremely fast-acting nerve toxin. It competes with acetylcholine, the major neurotransmitter, by bonding to acetylcholine receptors at nerve synapses and causing uncontrolled nerve firing. This disruption of normal nerve impulse activity results in rapid failure of those body systems that depend on nervous input for proper functioning. In insects, the action of nicotine is fairly selective, and only certain types of insects are affected.

Mammalian toxicity. Despite the fact that smokers regularly inhale small quantities of nicotine in tobacco smoke, nicotine in pure form is extremely toxic to mammals and is considered a Class I (most dangerous) poison. Nicotine is particularly hazardous because it penetrates skin, eyes, and mucous membranes readily; both inhalation and dermal contact may result in death. Ingestion is slightly less hazardous due to the effective detoxifying action of the liver.

Symptoms of nicotine poisoning are extreme nausea, vomiting, excess salivation, evacuation of bowels and bladder, mental confusion, tremors, convulsions, and finally death by respiratory failure and circulatory collapse. Poisoning occurs very rapidly and is often fatal. Treatment for nicotine poisoning is symptomatic, and only immediate treatment, including prolonged artificial respiration, may save a victim of nicotine poisoning.

Nicotine has been responsible for numerous serious poisonings and accidental deaths because of its rapid penetration of skin and mucous membranes and because of the concentrated form in which it is used.

Uses. Nicotine is used in greenhouses and gardens as a fumigant and contact poison to control soft-bodied sucking pests such as aphids, thrips, and mites. When nicotine sulfate is diluted with alkaline water or soap solutions, free nicotine alkaloid is liberated. Free nicotine is much more active than the sulfate form; it is fast acting and degrades completely within 24 hours, leaving no toxic residues. Non-alkaline nicotine sulfate sprays liberate the free alkaloid more slowly (over 24-48 hrs) and have limited use as stomach poisons for control of some leaf-eating pests. Certain roses and other ornamentals may be injured by nicotine sprays.

Tobacco teas are sometimes prepared by home gardeners for control of garden pests or for pests of houseplants. While these teas are not as toxic as nicotine sulfate sprays, any nicotine solution that is toxic enough to kill insects is also toxic enough to be harmful to humans.

Citrus Oil Extracts: Limonene and Linalool

Source. Crude citrus oils and the refined compounds d-limonene (hereafter referred to simply as limonene) and linalool are extracted from orange and other citrus fruit peels. Limonene, a terpene, constitutes about 90% of crude citrus oil, and is purified from the oil by steam distillation. Linalool, a terpene alcohol, is found in small quantities in citrus peel and in over 200 other herbs, flowers, fruits, and woods.

Terpenes and terpene alcohols are among the major components of many plant volatiles or essential oils. Other components of essential oils are ketones, aldehydes, esters, and various alcohols. Essential oils are the volatile compounds responsible for most of the tastes and scents of plants. Many of the essential oils also have some physiological activity.

Mode of action. The modes of action of limonene and linalool in insects are not fully understood. Limonene is thought to cause an increase in the spontaneous activity of sensory nerves. This heightened activity sends spurious information to motor nerves and results in twitching, lack of coordination, and convulsions. The central nervous system may also be affected, resulting in additional stimulation of motor nerves. Massive overstimulation of motor nerves leads to rapid knockdown paralysis. Adult fleas and other insects may recover from knockdown, however, unless limonene is synergized by PBO. Linalool is also synergized by PBO. Little has been published regarding the mode of action of linalool in insects.

Mammalian toxicity. Both limonene and linalool were granted GRAS (Generally Regarded As Safe—see "Terms to Understand") status by the United States Food and Drug Administration in 1965, and are used extensively as flavorings and scents in foods, cosmetics, soaps, and perfumes. Both compounds are considered safe when used for these purposes because they have low oral and dermal toxicities (see Table 1). At higher concentrations, however, limonene and linalool are physiologically active and may be irritating or toxic to mammals.

When applied topically, limonene is irritating to skin, eyes, and mucous membranes. Both limonene and linalool may be allergenic. Limonene acts as a topical vasodilator and a skin sensitizer; it was also shown to promote tumor formation in mouse skin that had been previously sensitized to tumor initiation (see Roe and Fielding, 1965). Linalool is more active as a systemic toxin than as a skin irritant.

Both compounds affect the central nervous system, and moderate to high doses applied topically to cats and other laboratory animals cause tremors, excess salivation, lack of coordination, and muscle weakness. Even at the higher doses, however, these symptoms are temporary (lasting several hours to several days), and animals recover fully. Some cats may experience minor tremors and excess salivation for up to one hour after applications of limonene or linalool at recommended rates.

Crude citrus peel oils and products prepared with the crude oils may be more toxic to animals than products containing purified limonene or linalool. Adequate research on the toxicity of crude citrus oils has not been conducted, and they are not recommended for use on animals.

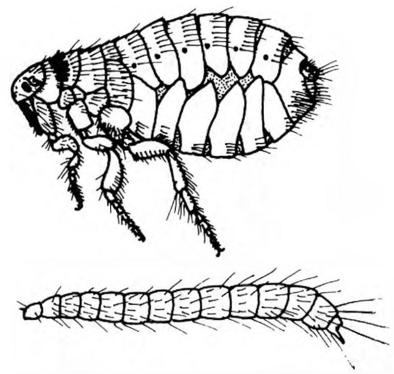


Figure 4. The cat flea, adult and larva. The citrus oil derivatives, limonene and linalool, are registered for use in controlling adult fleas on cats and dogs. Linalool also is registered for use in controlling all stages of fleas throughout the home.

Uses. Limonene and linalool are contact poisons and may also have some fumigant action against fleas. Both compounds are formulated as flea dips and shampoos. They also are included in some pet shampoos that do not directly claim to have insecticidal properties. These products are relatively new, and while showing promise, some questions persist concerning their toxicity. Citrus oil extracts have also been combined with insecticidal soap for use as contact poisons against aphids and mites; published evaluations of the effectiveness of these combinations are lacking. Linalool and limonene evaporate readily from treated surfaces, and provide no residual control. Both compounds are most effective when synergized with PBO.

Other Essential Plant Oils: "Herbal" Repellents and Insecticides

Essential oils are volatile, odorous oils derived from plant sources. Although they are used mainly as flavorings and fragrances in foods, cosmetics, soaps, and perfumes, some of them also have insect repellent or insecticidal properties. Many essential oils have GRAS (Generally Regarded As Safe) status; however, when applied topically at high concentrations they tend to be irritating to skin and mucous membranes. They are sometimes used as topical counterirritants to relieve or mask pain. Many of the essential oils that have low dermal toxicity may be toxic by ingestion.

The most common essential oils used as repellents are the oils of cedar, lavender, eucalyptus, pennyroyal, and citronella. They are used mostly on pets and humans to repel fleas and mosquitoes. With the exception of pennyroyal, these essential oils are thought to pose little risk to people or pets, though they should not be used above recommended rates. Some herbal pet products that contain essential oils recommend use daily or "as often as needed." These products should be used moderately and with careful observation of the pet to spot early signs of skin irritation or possible toxic effects.

Oil of pennyroyal contains pulegone, a potent toxin that can cause death in humans at doses as low as one tablespoon when ingested. At lower internal doses it may cause abortion, liver damage, and renal failure. Although the dermal toxicity of pennyroyal is fairly low, some cats are susceptible to poisoning by topical application of oil of pennyroyal, possibly because they ingest it during grooming.

Citronella is sold mainly in the form of candles to be burned outdoors to repel mosquitoes from back yards or other small areas. It is also contained in some "natural" mosquito repellent lotions. Before the development of synthetic repellents, citronella was the most effective mosquito repellent available. Despite its wide usage, there is little scientific information available regarding its efficacy or mammalian toxicity.

Neem

Source. Neem products are derived from the neem tree, *Azadirachta indica,* that grows in arid tropical and subtropical regions on several continents. The principle active compound in neem is azadirachtin, a bitter, complex chemical that is both a feeding deterrent and a growth regulator. Meliantriol, salannin, and many other minor components of neem are also active in various ways. Neem products include teas and dusts made from leaves and bark, extracts from whole fruits, seeds, or seed kernels, and an oil expressed from the seed kernel.

Mode of action. Neem is a complex mixture of biologically active materials, and it is difficult to pinpoint the exact modes of action of various extracts or preparations. In insects, neem is most active as a feeding deterrent, but in various forms it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant, sterilant, or toxin.

As a repellent, neem prevents insects from initiating feeding. As a feeding deterrent, it causes insects to stop feeding, either immediately after the first "taste" (due to the presence of deterrent taste factors), or at some point soon after ingesting the food (due to secondary hormonal or physiological effects of the deterrent substance). As a growth regulator, neem is thought to disrupt normal development by interfering with insect hormone production or reception, thereby preventing insects from reaching reproductive maturity. Susceptibility to the various effects of neem differs by species.

Mammalian toxicity. Neem has extremely low mammalian toxicity (see Table 1), and in most forms is non-irritating to skin and mucous membranes. The seed dust, however, may be extremely irritating to some people. In humans, neem has various pharmacological effects. Some of these effects are beneficial, such as lowering blood pressure and reducing inflammation and fever. Neem is also an anti-fungal agent. In addition, neem has anti-ulcer and strong spermicidal properties, depending on the type of extract. Neem is not mutagenic according to the Ames Test. It has been used in India and Asia for centuries for a multitude of practical and medicinal purposes.

Uses. Neem is not currently registered by the US EPA, and there are no commercial neem products available in the United States. For a short while, a neem product known as Margosan-O was registered for control of gypsy moths and greenhouse leaf miners, but that registration is no longer active. Several companies are investigating the development of new neem products for controlling insects on food crops as well as nonfood crops.

Research has shown that neem has some systemic action in plants. When applied as a dust to soils, neem can be taken up by the roots of some species and translocated to other parts of the plant. Neem may remain active in the soil for up to 4 weeks, depending on soil conditions. Foliar applications of neem are systemic only to a limited extent, and new foliage must be sprayed periodically for adequate protection.

In India, Asia, and Africa, neem is used as a protectant of stored grains and as a broad-spectrum repellent and feeding deterrent for field crops. Repellents and deterrents are effective only when applied over wide areas, however, because the target insects are only deterred rather than killed. Hunger may force some insects to move from treated areas to nearby crops that are left unprotected.

INSECTICIDAL SOAPS

Source. Insecticidal soaps generally are not considered to be botanical insecticides, although the oils from which they are produced may be of plant origin. In chemical terms, insecticidal soaps (and all soaps in general) are made from the salts of fatty acids. Fatty acids are the principle components of the fats and oils found in animals and plants.

Numerous studies have been conducted to correlate insecticidal activity with the physical structure of fatty acids, and certain acids have been determined to be most insecticidal. Oleic acid, present in high quantities in olive oil and in lesser amounts in other vegetable oils, is especially effective. Safer® soaps, the most common currently available insecticidal soaps, contain potassium oleate (the potassium salt of oleic acid) as the active ingredient.

This section refers only to those products whose active insecticidal ingredient is the soap itself. Some insecticidal products contain soaps or shampoos in combination with organophosphates (for control of lice) or other kinds of insecticides (for control of fleas on pets). Such *insecticide-containing* soaps are not included in this discussion of *insecticidal* soaps.

Figure 5. Safer, Inc. is the main producer of insecticidal soaps for use in and around the home as well as in commercial operations. Safer soaps are formulated for many uses and are sold as concentrates or ready-to-use sprays.

Mode of action. Despite many years of use, the mode of action of insecticidal soaps still remains somewhat unclear. Although the action of soaps involves some physical disruption of the insect cuticle (the outer body covering), additional toxic action is suspected. Some evidence indicates that soaps enter the insect's respiratory system and cause internal cell damage by breaking down cell membranes or disrupting cell metabolism. Soaps also exert some non-lethal developmental effects on immature insects.

Mammalian toxicity. The mammalian toxicity of insecticidal soaps is basically the same as that of any soap or detergent. Ingestion causes vomiting and general gastric upset, but has no serious systemic consequences. Insectidal soap concentrates may contain ethanol (up to 30%), which causes intoxication at doses above several ounces; however, vomiting is likely to clear most of the alcohol from the system before it is absorbed into the bloodstream. Externally, soaps are irritating to eyes and mucous membranes and have drying effects on skin.

Some insecticidal soap products contain additional insecticidal compounds such as pyrethrins or citrus oil derivatives. These combination products have a higher toxicity than products containing only soap, and their additional toxic effects depend on the kinds of insecticides added.

Uses. Soaps are used as contact insecticides to control soft-bodied pests such as aphids, thrips, scales (crawler stage only), whiteflies, leafhopper nymphs, and mites. Soaps are effective only against those insects that come into direct contact with the spray before it has dried. Dried residues on plant surfaces are not insecticidal, and they degrade rapidly.

Soaps are not effective against insects with heavier cuticles, such as adult beetles, bees, wasps, flies, or grasshoppers. In addition, highly mobile insects may escape soap spray applications by flying away. Mobility and a hardened cuticle protect the adult forms of most beneficial insects such as lady beetles, lacewings, or syrphid flies from the toxic action of soaps. The immature forms of these insects are flightless and soft-bodied, however, and may be more susceptible to injury from soaps.

Soaps are particularly useful for controlling pests of ornamental plants and houseplants, though they may be phytotoxic to some plant species. Plants that have pubescent (hairy) leaves may be more susceptible to soap injury than smooth-leafed plants because the hairs tend to hold the soap solution on the leaf surface where a lens effect may cause burning.

In addition to commercial insecticidal soaps, many common household soaps and detergents are insecticidal when applied to plants as a 1-2% aqueous solution. Dishwashing liquids and laundry detergents are designed to dissolve grease, however, and they may cause plant injury by dissolving the waxy cuticle on leaf surfaces. Also, detergents differ from soaps chemically and are sometimes more phytotoxic. Plant injury may possibly be avoided if the soap or detergent is rinsed from plant surfaces shortly after application. Commercial insecticidal soaps are less likely to dissolve plant waxes than household cleaning products.

CAUTION: Although homemade soap sprays may be fairly harmless, creating homemade poisons for pest control can be a dangerous practice. Some "recipes" for pesticides call for cleaning agents, fuel oils, polishes, solvents, and other materials that are toxic to plants and many animals (including humans). The fact that these chemicals are not generally considered to be pesticides does not mean that they are not toxic. Many of them are very toxic! Readers are strongly urged not to prepare homemade pesticides from household chemicals.

SUMMARY

Botanical insecticides and insecticidal soaps share a number of advantages. Foremost among these are their rapid degradation in the environment and their rapid action in insects. Rapid degradation is beneficial because it minimizes the risks posed by unwanted insecticide residues in food, water, and the environment in general. Rapid action in insects is advantageous because it serves to minimize the extent of feeding damage. On the other hand, rapid degradation imposes certain limitations on the use of botanicals. Where persistent residues are needed for continuous control, botanicals and soaps do not provide adequate protection.

The safety of botanical insecticides and insecticidal soaps in general is a topic that deserves careful consideration. Many of the insecticides discussed in this publication are attractive alternatives to synthetics because, in addition to their rapid degradation, they have low mammalian toxicities (high LD_{50} values). Pyrethrins, sabadilla, limonene, linalool, and the insecticidal soaps fall into this category.

It is very important, nevertheless, to note that all botanical insecticides are ***not*** safer than all synthetic insecticides simply because they are "natural." Ryania and rotenone are comparable in acute toxicity to commonly used synthetic insecticides such as malathion, carbaryl, diazinon, and permethrin. Nicotine is extremely toxic to mammals by both inhalation and dermal exposure. In addition, the chronic effects of repeated exposures to any insecticide—whether natural or synthetic—are not fully understood and are difficult to test realistically. Users are reminded to always read and follow pesticide label directions exactly and to wear proper protective clothing (long sleeves and long pants, shoes and socks, rubber or neoprene gloves, protective eye wear, and a respirator or dust mask) when applying any pesticide, natural or synthetic.

Finally, readers are encouraged to employ effective nonchemical control measures whenever possible. These may include crop rotation, sanitation, or other cultural controls, the release or conservation of beneficial insects, or the use of resistant crop varieties.

Terms to Understand

Carcinogen: a substance or agent that produces or incites cancer (malignant tumors) in experimental animals or in humans.

Contact Poison: a toxin that kills insects by contact; it does not have to be ingested to be effective. A contact poison either kills insects immediately (as they are touched by the wet spray) and then degrades quickly—as with pyrethrins or soaps—or has some residual action and kills insects over time (as they come into contact with the poison on plant surfaces)—as with the botanical insecticide sabadilla and the synthetic compounds carbaryl (Sevin) and permethrin, as well as many others.

G.R.A.S.: "Generally Regarded As Safe," a classification assigned by the Food and Drug Administration to certain compounds that have been used traditionally without apparent toxicity or are believed to be low enough in mammalian

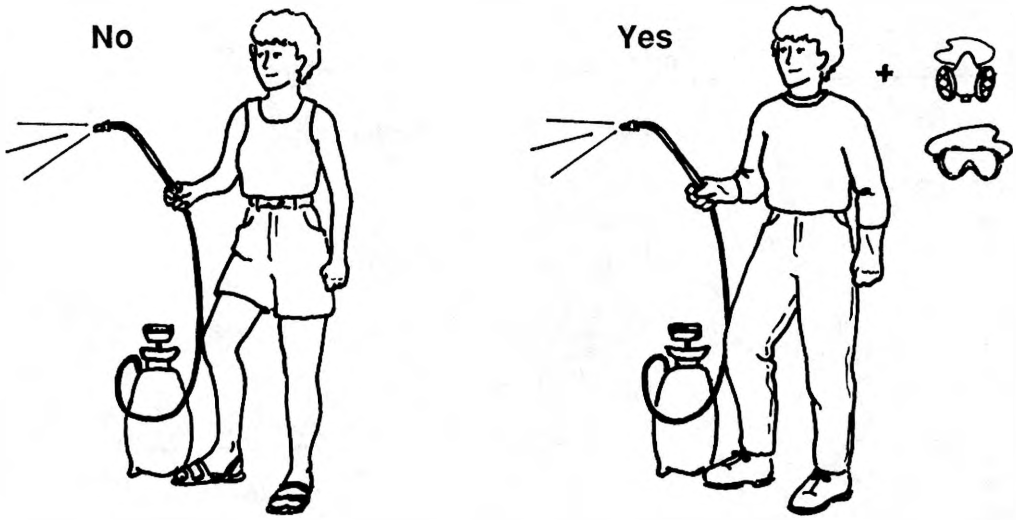


Figure 6. Applying pesticides of any sort is serious business requiring some degree of protection. Even though the active ingredients in most naturally occurring insecticides are relatively low in toxicity, they are often allergenic or irritating. The inert ingredients (solvents, carriers, and other additives) in formulated products also may be irritating to eyes, lungs, and skin.

Proper protective clothing should be worn whenever mixing concentrates or applying sprays or dusts. Essential protection includes a loose-fitting, long-sleeved shirt and long pants, rubber boots or sturdy, closed shoes, and rubber gloves (not cloth or leather, as they can absorb toxins). Safety goggles and a cartridge respirator are recommended when mixing concentrates or when apply sprays or dusts in greenhouses or other enclosed areas where contact with fumes or airborne particles is likely.

toxicity that certain testing requirements are waived during the pesticide registration process.

Hazard: the risk associated with the use of a formulated pesticide. Hazard depends on several factors including the inherent toxicity of the active ingredients, the formulation (the form in which the product is used, such as liquid concentrate, wettable powder, ready-to-use spray, etc.), and the degree of exposure. Hazard, or risk, is sometimes defined as "toxicity exposure."

LD_{50}: the abbreviation for "median lethal dose," the dose that kills 50% of the population of test animals. When dealing with pesticides, the LD_{50} values most commonly encountered are the mammalian oral and dermal LD_{50} values (measured in rats, mice, rabbits, etc.) These measurements provide an estimate of how toxic a substance might be to humans. LD_{50} values are usually reported in terms of milligrams of toxicant per kilogram of body weight of the test animal (mg/kg), so a lower LD_{50} indicates a more toxic substance.

Repellent: a volatile substance that keeps insects from alighting or feeding. Repellents are usually used to fend off mosquitoes, flies, fleas, ticks, and gnats (biting pests of humans and other animals).

Signal Words: the words on a pesticide label that indicate the toxicity of the active ingredients. Although based on toxicity alone, signal words give an indication of potential hazard (see Table 2).

Table 2
Signal Words

Signal Word	Toxicity Category	Toxicity Rating	Oral LD_{50}
"DANGER" or	I	extremely toxic	
"DANGER-POISON"			0-50
"WARNING"	II	very toxic	50-500
"CAUTION"	III	moderately toxic	500-5000
"CAUTION"	IV	slightly toxic or practically nontoxic	>5000

Stomach Poison: a toxin that must be ingested to be effective. A stomach poison usually has some residual activity, so that it remains active until insects have a chance to feed on it. Most stomach poisons are used against plant-feeding insects or insects that will feed on baits. They are generally not effective against insects that suck plant sap. Rotenone and ryania are active as stomach poisons.

Synergist: in terms of pesticides, a material that is itself low in toxicity but increases the toxicity of the pesticide with which it is combined. Most synergists act by inhibiting the detoxification enzymes of the target pest, so that the pesticide has longer to act before being degraded in the insect's system.

Tolerance: the amount of pesticide residue permitted by the United States Environmental Protection Agency or the Food and Drug Administration to be present in or on raw agricultural commodities or processed or semi-processed food or feed products.

Toxicity: the degree to which a substance is inherently poisonous (able to cause injury or death). The toxicity of pesticides is often expressed as an LD_{50} for the technical material (the pure active ingredient) in laboratory animals.

ACKNOWLEDGMENT

The following reviewers contributed to this publication: M.D. Atkins, Safer, Inc.; Whitney Cranshaw, Colorado State University; Martin Jacobson, USDA, Beltsville; Donald Kuhlman, Cooperative Extension Service, University of Illinois; Diane Matthews-Gehringer, Rodale Research Center; Shirley McClellan, Illinois Natural History Survey; Frederick W. Plapp, Texas A & M University; John Williams, Necessary Trading Company. Funding to develop this publication was provided in part by a grant from the Illinois Department of Energy and Natural Resources (ENR Project No. IP13) and by the Cooperative Extension Service, University of Illinois.

REFERENCES

Casida, J.E. 1973. Pyrethrum: The Natural Insecticide. Academic Press, New York. 329 pp.

Farm Chemicals Handbook '89, 75th Anniversary Issue. 1989. Meister Publishing Company.

Grainge, M., and S. Ahmed. 1988. Handbook of Plants with Pest-Control Properties. John Wiley and Sons, New York. 470 pp.

Hayes, W.J. 1982. Pesticides derived from plants and other organisms. In: W.J. Hayes, ed. Pesticides Studied in Man. Williams and Wilkins, Baltimore. pp. 75-111.

Hooser, S.B., V.R. Beasley, and J.I. Everitt. 1986. Effects of an insecticidal dip containing d-limonene in the cat. J Amer Vet Med Assoc 189(8): 905-908.

Jacobson, M. 1958. Insecticides from Plants: A Review of the Literature, 1941-1953. USDA Agr Handbook 154. 299 pp.

Jacobson, M. 1975. Insecticides from Plants: A Review of the Literature, 1954-1971. USDA Agr Handbook 461. 138 pp.

Jacobson, M. 1989. Focus on Phytochemical Pesticides, Vol. I. The Neem Tree. CRC Press, Boca Raton. 178 pp.

Jacobson, M., and D.G. Crosby. 1971. Naturally Occurring Insecticides. Marcel Dekker, New York. 585 pp.

McIndoo, N.C., and A.F. Sievers. 1924. Plants tested for or reported to possess insecticidal properties. USDA Bull 1201.

Powers, K.A. 1985. Toxicological aspects of linalool: A review. Vet and Human Toxicol 27(6): 484-486.

Roe, F.J., and W.E. Field. 1965. Chronic toxicity of essential oils and certain other products of natural origin. Food and Cosmetic Toxicol 3: 311-324.

Schmutterer, H., K.R.S. Ascher, and H. Rembold. 1982. Natural Pesticides from the Neem Tree (*Azadirachta indica* A. Juss.). Eschborn, Rottach-Egern, FRG. 297 pp.

United States Environmental Protection Agency. 1989. Guidance for the Reregistration of Pesticide Products Containing Rotenone as the Active Ingredient. EPA Office of Pesticide Programs, Washington, D.C. 116 pp.

Yamamoto, I. 1970. Mode of action of pyrethroids, nicotinoids, and rotenoids. Ann Rev Entomol 15: 257-272.

Insecticide Formulations and Toxicities

The following list of insecticides is intended as a reference for their trade and common names, toxicities, formulations, and manufacturers. In addition to the insecticides recommended in the Insect Pest Management Guides, we have included some that have label approval but are not in the Illinois recommendations and some that are still experimental compounds.

The index of trade names of insecticides, listed alphabetically, will allow you to find quickly the appropriate common name. Within the body of the reference, the approved common names are also listed alphabetically in the left-hand column. Trade names, formulations, toxicities, signal words, and manufacturers are listed for each product.

The use of product names does not constitute an endorsement by the University of Illinois. Ultimate reliance must be placed on directions and information supplied by manufacturers or on product labels.

Oral and dermal toxicity values are expressed as LD_{50}, which indicates the size of the dose that is lethal to 50 percent of the test animals. LD_{50} is expressed as milligrams (mg) of actual insecticide per kilogram (kg) of body weight of the test animal--mg/kg. Most of the oral and dermal LD_{50} values we have used on our list are printed in the 8th edition of *The Pesticide Manual: A World Compendium*, published in 1987 by the British Crop Protection Council (Lavenham Press Ltd.). Oral and dermal LD_{50} values reported from other sources sometimes differ markedly, depending on the carrier of the toxicant, the ratio of isomers in the sample, and the species, sex, age, and degree of fasting of the test animals. Acute oral toxicity values are usually obtained by feeding technical-grade product to white rats or rabbits; acute dermal values are determined by skin absorption tests on rats or rabbits. However, white mice, guinea pigs, dogs, and other animals are sometimes used for these tests. Whenever possible, we have used the data reported for either white rats or rabbits. Because test results vary, an LD_{50} may be expressed as a range of values rather than a single value.

By multiplying the LD_{50} value by 0.003, you can approximate the ounces of actual insecticide required to be lethal to one of every two 187-pound men or other warm-blooded animals. As an example, an oral LD_{50} value for malathion is 1,200 mg/kg; thus, if a group of men each weighing 187 pounds ate 3.6 ounces (1,200 times 0.003) of actual malathion per man, half of them would probably die. The dermal-toxicity-LD_{50} value of malathion is approximately 4,000 mg/kg, or, for a 187-pound man, 12 ounces. If you check the list of insecticides, you will find some highly toxic chemicals with LD_{50} values from 1 to 10 mg/kg. For the average-size man, fatal doses of those chemicals would be in the range of 0.003 to 0.03 ounce.

LD_{50} values are approximate, but they serve as a guide for comparing the toxicities of insecticides as well as an indication of their comparative acute toxicities to other warm-blooded animals and man. Acute toxicity values expressed as LD_{50} are classified according to their relative danger when being used. An acute oral LD_{50} of 500 mg/kg or higher is rated as low toxicity; an LD_{50} rating of 50 to 500 is moderate; and 50 or less is high.

When available, ratings of insecticide toxicity to fish, birds, and honey bees are also given. Those for bees can be interpreted readily as follows: (1) high--kills bees on contact and by residues; bees should be removed from area of application; (2) moderate--kills bees if applied over them; limited damage with correct dosage, timing, and method of application; (3) low--can be used around bees with few precautions and a minimum of injury. However, the relative toxicities of insecticides to fish and birds must be interpreted from the available data. The primary test species for fish are rainbow trout and bluegills, but goldfish, golden orfe, carp, bass, catfish, guppies, harlequin fish, minnows, and mosquito fish have also been used by a number of different laboratories. The primary test species for birds are bobwhite quail, ringneck pheasants, and mallard ducks, but chickens, Japanese quail, canaries, ducks, pigeons, blackbirds, starlings, and partridges have also been used. As a consequence, the data for toxicity of various insecticides to fish and birds should be viewed as relative ratings.

Factual errors arising during the transcription of the information from *The Pesticide Manual* are our responsibility. Please draw our attention to any errors or omissions in the following list so that we can make corrections to our next annual revision.

Remember, this is NOT a list of recommended insecticides, nor is it to be used in determining what insecticide to use to control a particular insect. This list is a reference to compare common names of insecticides with trade names and to determine their relative toxicities and general use.

INDEX: INSECTICIDE TRADE NAMES

Trade name	Common name
Aastar	combination of phorate and flucythrinate
Abate	temephos
Actellic	pirimiphos-methyl
Agrox D-L Plus	combination of captan, diazinon, and lindane
Alleviate	allethrin
Altosid	methoprene
Ambush	permethrin
Ammo	cypermethrin
Anthon	trichlorfon
Arrivo	cypermethrin
Asana	esfenvalerate
Atroban	permethrin
Avid	avermectin
Azodrin	monocrotophos
Bactimos	*Bacillus thuringiensis* var. *israelensis*
Bactospeine	*Bacillus thuringiensis* var. *kurstaki*
Baygon	propoxur
Baytex	fenthion
Baythroid	cyfluthrin
Bidrin	dicrotophos
Black Leaf 40	nicotine
Bolstar	sulprofos
Brigade	bifenthrin
Broot	trimethacarb
Capture	bifenthrin
Carzol	formetanate
Chlor-O-Pic	chloropicrin
Ciodrin	crotoxyphos
Ciovap	combination of crotoxyphos and dichlorvos
Co-Ral	coumaphos
Combot	trichlorfon
Comite	propargite
Counter	terbufos
Cygon	dimethoate
Cymbush	cypermethrin
Cythion	malathion
Dasanit	fensulfothion
DDVP	dichlorvos
De-Fend	dimethoate
Delnav	dioxathion
Deltic	dioxathion
Demon	cypermethrin
Derris	rotenone
Detia	aluminum phosphide
Diacon	methoprene
Diazinon	diazinon
Dibrom	naled
Dimecron	phosphamidon
Dimilin	diflubenzuron
Dipel	*Bacillus thuringiensis* var. *kurstaki*
Dipterex	trichlorfon
Di-Syston	disulfoton
DNOC	dinitro compounds
Doom	*Bacillus popilliae*
Dragnet	permethrin
Dursban	chlorpyrifos
Dycarb	bendiocarb
Dyfonate	fonofos
Dylox	trichlorfon
D·Z·N	diazinon
Ecopro	temephos
Ectiban	permethrin
Ectrin	fenvalerate
EDC	ethylene dichloride
Elgetol	dinitro compounds
Entex	fenthion
Equibot	trichlorfon
Eqvalon	ivermectin
Expar	permethrin
Famphos	famphur
Ficam	bendiocarb
Force	tefluthrin
Fumitoxin	aluminum phosphide
Furadan	carbofuran
Gammasan	lindane
Gastoxin	aluminum phosphide
Gencor	hydroprene
Germate Plus	lindane + diazinon
Grasshopper spore	*Nosema locustae*
Guardian	flucythrinate
Guthion	azinphos-methyl
HCN	hydrocyanic acid
Imidan	phosmet
Insectrin	permethrin
Isotox	lindane
Ivomec	ivermectin
Javelin	*Bacillus thuringiensis* var. *kurstaki*
Karate	lambda-cyhalothrin
Karathane	dinocap
Kelthane	dicofol
Knox Out	diazinon
Lannate	methomyl
Larvin	thiodicarb
Larvacide	chloropicrin
Larvadex	cyromazine

Trade name	Common name
Lorsban	chlorpyrifos
Lysoff	fenthion
Marlate	methoxychlor
Mavrik	fluvalinate
Mesurol	methiocarb
Metasystox-R	oxydemeton-methyl
Metho-gas	methyl bromide
Mocap	ethoprop
Monitor	methamidophos
Moorman's IGR	methoprene
Morestan	oxythioquinox
Neguvon	trichlorfon
Nemacur	fenamiphos
Neo-Pynamin	tetramethrin
Nudrin	methomyl
Off	deet
Oftanol	isofenphos
Omite	propargite
Orthene	acephate
Overtime	permethrin
Pay-Off	flucythrinate
PDB	paradichlorobenzene
Penncap-M	methyl parathion (encapsulated)
Pentac	dienochlor
Permaban	permethrin
Permectrin	permethrin
Pharorid	methoprene
Phosdrin	mevinphos
Phostek	aluminum phosphide
Phostoxin	aluminum phosphide
Phthalthrin	tetramethrin
Plictran	cyhexatin
Pounce	permethrin
Pramex	permethrin
Precor	methoprene
Premgard	resmethrin
Prolate	phosmet
Proxol	trichlorfon
Pryfon	isofenphos
PT470 Regulator	fenoxycarb
Pydrin	fenvalerate
Pynamin	allethrin
Pyrenone	pyrethrins
Pyrid	fenvalerate
Quasar	chloropicrin
Rabon	tetrachlorvinphos
Ravap	combination of dichlorvos and tetrachlorvinphos
Reldan	chlorpyrifos-methyl
Respond	resmethrin
Safrotin	propetamphos
Savit	carbaryl
Scourge	resmethrin
Scout	tralomethrin
Sevin	carbaryl
SOK-BT	*Bacillus thuringiensis* var. *kurstaki*
Spectracide	diazinon
Spotton	fenthion
Spur	fluvalinate
Supracide	methidathion
Synerid	erythrosine-B
Synthrin	resmethrin
Systox	demeton
Taktic	amitraz
Talstar	bifenthrin
Tedion	tetradifon
Teknar	*Bacillus thuringiensis* var. *israelensis*
Temik	aldicarb
Tempo	cyfluthrin
Terminator	diazinon
Tetralate	combination of tetramethrin and resmethrin
Thimet	phorate
Thiodan	endosulfan
Thuricide	*Bacillus thuringiensis* var. *kurstaki*
Tiguvon	fenthion
Tomahawk	pirimiphos-methyl
Topside	*Bacillus thuringiensis* var. *kurstaki*
Torpedo	permethrin
Trigard	cyromazine
Trithion	carbophenothion
Triumph	miral
Turcam	bendiocarb
Vapona	dichlorvos
Vectobac	*Bacillus thuringiensis* var. *israelensis*
Vendex	hexakis
Vigilante	diflubenzuron
Vydate	oxamyl
Warbex	famphur
Zectran	mexacarbate
Zolone	phosalone

INSECTICIDE FORMULATIONS AND TOXICITIES

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
acephate (Chevron)	Orthene	75SP	L	H	M	866-945	>2,000	caution
aldicarb (Rhone-Poulenc)	Temik	10G, 15G	-	H	M	1	5	danger
allethrin (Stauffer, Fairfield Am.)	Alleviate, Pynamin	many	H	L	L	685-1,100	>2,500	caution
aluminum phosphide (Degesch Am.)	Detia, Fumitoxin, Gastoxin, Phostek, Phostoxin	55% tablets, pellets	-	-	-	AV[d] 2,000 ppm		danger
amitraz (NOR-AM)	Taktic	12.5% EC	-	L	-	800	>1,600	warning
avermectin (Merck)	Avid	EC	M	H	M	650	2,000	caution
azinphos-methyl (Mobay)	Guthion	2S, 2L, 50WP	VH	H	M	16	>250	danger
Bacillus popilliae (Reuter, Fairfax Biological)	Doom	WP	EL	EL	EL	NT[e]	NT	caution
Bacillus thuringiensis var. *isrelensis* (Abbott Labs, Biochem, Sandoz)	Bactimos, Teknar, Vectobac	F, G, L, WP	EL	EL	EL	NT	NT	caution
Bacillus thuringiensis var. *kurstaki* (Abbott Labs, Biochem, Tuco, Sandoz, NOR-AM, Reuter)	Bactospeine, Dipel Javelin, SOK-Bt, Thuricide, Topside	many	EL	EL	EL	NT	NT	caution
bendiocarb (NOR-AM)	Dycarb, Ficam, Turcam	29 and 76WP, 1D, 25% oil suspension	-	H	-	40-156	566-600	warning
benzyl benzoate	...	30L	-	-	-	500-5,000	...	caution
bifenthrin (FMC)	Brigade, Capture, Talstar	10WP, EC	VH	H	L	54	>2,000	warning
carbaryl (Rhone-Poulenc)	Sevin	XLR, 4-oil, 80S, 50W, 4F, Bait	VL	H	VL	850	>4,000	caution warning
carbofuran (FMC, Mobay)	Furadan	3G, 5G, 10G, 15G, 4F	M	H	M	8-14	>2,550	warning danger
carbophenothion (ICI)	Trition	EC	VH	H	-	20-79	1,850	warning
chloropicrin (Great Lakes, Niklor, IMC)	Chlor-o-pic, Larvacide 100, Quasar	liquid fumigant	-	-	-	AV 20 ppm CV 0.1 ppm		danger
chlorpyrifos (Dow)	Dursban, Lorsban	2E, 4E, 15G, 50W, 50SL, others	VH	H	H	135-163	2,000	caution warning
chlorpyrifos-methyl (Dow)	Reldan	4E	-	-	-	1,630-2,140	>2,000	warning
coumaphos (Bayer AG)	Co-Ral	25WP, pour-on, EC, D, F	M	M	H	13-963	860-1,000+	warning danger

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
crotoxyphos (DuPont, SDS Biotech)	Ciodrin	EC, D, oils	H	M	-	53	384	danger
cyfluthrin (Mobay)	Baythroid, Tempo	0.05G, 2E	VH	H	L	500-1,200	>5,000	caution
cyhexatin (Dow)	Plictran	50W	VH	L	-	540	>2,000	warning
cypermethrin (FMC, ICI)	Ammo, Arrivo, Cymbush, Demon	EC, WP	VH	H	L	251-4,123	>2,400	warning
cyromazine (CIBA-Geigy)	Larvadex, Trigard	0.3% feed premix, 75WP (insect growth regulator)	L	VL	-	3,387	>3,100	caution
deet (McLaughlin-King)	Off	in alcohol	-	-	-	2,000	10,000	caution
demeton (Mobay)	Systox	2E, 6E	M	M	M	2-12	14	danger
diazinon (CIBA-Geigy, Pennwalt)	D·Z·N, Knox Out, Spectracide, Terminator eartags	4E, 14G, 50W, AG500, 2F, ear tags	H	H	H	300-400	>2,150	caution warning
dichlorvos (CIBA-Geigy, SDS Biotech, DuPont)	DDVP, Vapona, others	many	M	H	M	56-108	75-210	danger
dicofol (Rohm and Haas)	Kelthane	1.6EC, 35WP	M	L	L	668-842	1,870	caution warning
dicrotophos (DuPont, CIBA-Geigy)	Bidrin	8M	-	H	H	17-22	111-181	danger
dienochlor (Sandoz)	Pentac	4F, 50WP	-	L	L	>3,160	>3,160	warning
diflubenzuron (Uniroyal)	Dimilin, Vigilante	25W, 4G, Bolus	VL	VL	VL	>4,640	>2,000	caution
dimethoate (Am. Cyanamid)	Cygon	400(4E), 2.67E	VL	H	M	180-336	>800	warning
dinitro compounds (Pennwalt)	DNOC, Elgetol, others	WP, F, flakes, salts	-	-	-	37-50	80-200	danger
dinocap (Rohm and Haas)	Karathane	WP, LC, D	-	-	L	980-1,190	>4,700	caution
dioxathion (NOR-AM)	Delnav, Deltic	EC	H	L	VL	23-43	63-235	danger
disulfoton (Mobay, Sandoz)	Di-Syston	8E, 15G	M	M	M	3-12	20	danger
endosulfan (FMC)	Thiodan	2EC, 3EC, 50WP	VH	M	M	80-110	359	warning danger
erythrosine-B (Hilton-Davis)	Synerid	bait	-	-	-	6,700-7,000	-	caution
esfenvalerate (DuPont)	Asana	1.9EC	H	H	L	75	>2,000	danger
ethion (FMC, Rhone-Poulenc)	Ethion	8E, 5G, 4M, superior 70 oil, 25WP	H	M	VL	24	915	warning

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
ethoprop (Rhone-Poulenc)	Mocap	10G, 15G, 6E	H	M	M	62	26	warning danger
ethylene dichloride (PPG Industries)	EDC	liquid fumigant	-	-	-	670-890 AV 1,000 ppm	...	danger
eugenol (several)	...	attractant	-	-	-	500-5,000	...	...
famphur (Am. Cyanamid)	Famphos, Warbex	pour-on	-	H	H	48	2,730	danger
fenamiphos (Mobay)	Nemacur	EC, G	H	-	-	15-19	500	danger
fenoxycarb (R. Maag AG)	Pt470 Regulator	aerosol	-	-	-	>10,000	>2,000	warning
fensulfothion (Mobay)	Dasanit	15G, spray concentrate	H	H	H	5-11	3-30	danger
fenthion (Mobay)	Baytex, Entex, Lysoff, Tiguvon, Spotton	pour-on, spray concentrate	H	H	VH	190-615	330-500	warning
fenvalerate (DuPont)	Ectrin, Pydrin, Pyrid	2.4EC, 6.48EC, 10L, eartags	VH	H	L	451	>5,000	caution warning
flucythrinate (Am. Cyanamid)	Guardian, Pay-Off	2.5EC, eartags	VH	H	L	67-81	>1,000	danger
fluvalinate (Sandoz)	Mavrik, Spur	2E, 23.3F	VH	-	-	260-280	>20,000	danger
fonofos (ICI)	Dyfonate	4E, 10G, 20G	-	M	M	11-24	159	danger warning
formetanate (NOR-AM)	Carzol	92WP	M	M	L	21	>5,600	danger
geraniol (several)	...	attractant	-	-	-	...	...	...
gyplure (National Chemical)	Disparlure	attractant	-	-	-	...	...	...
hexakis (DuPont)	Vendex	50WP, 4L	-	-	-	2,630	>2,000	danger
hydrocyanic acid (several)	HCN	fumigant	-	-	-	4 AV 40 ppm, CV 10 ppm	...	danger
hydroprene (Sandoz)	Gencor	EC	-	-	-	>5,100	>5,100	caution
isofenphos (Mobay)	Oftanol, Pryfon	G, EC	H	-	H	28-39	>1	danger
ivermectin (Merck)	Eqvalon, Ivomec	RTU injectable, RTU paste	M	H	M	650	2,000	caution
lambda-cyhalothrin (ICI)	Karate	EC	H	-	-	56-79	632	...
lead arsenate (Drevel, Mechema Chemical)	...	...	-	H	L	1,050	>2,400	danger

INSECTICIDE FORMULATIONS AND TOXICITIES

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
lindane (Rhone-Poulenc)	several	many	H	H	M	88-270	900-1,000	warning
malathion (Am. Cyanamid, Rhone-Poulenc)	Cythion, Malathion, others	57EC, ULV, others	M	H	L	2,800	4,100	caution
metaldehyde (several)	several	bait	-	-	-	630	...	caution warning
methamidophos (Chevron, Mobay)	Monitor, others	4L	-	H	-	30	50-110	danger
methidathion (CIBA-Geigy)	Supracide	2E	H	H	M	25-54	1,546	danger
methiocarb (Mobay)	Mesurol	75WP, bait, powder	H	H	L	100	350-400	warning
methomyl (DuPont)	Lannate, Nudrin	90SP, 1.8L, 2.4LV	M	H	L	17-24	>5,000	danger
methoprene (Sandoz)	Altosid, Diacron, Moorman's IGR, Pharorid, Precor	EC, bait	VL	L	VL	>34,600	3,500	caution
methoxychlor (Hopkins, Prentiss)	Marlate	many	H	L	VL	6,000	2,820	caution
methyl bromide (Great Lakes Chemical)	Metho-gas, others	liquid fumigant	-	-	-	AV 200 ppm CV 20 ppm		danger
methyl parathion (Monsanto)	many	EC, WP, D	M	H	H	14-24	67	danger
methyl parathion, encapsulated (Pennwalt)	Penncap-M	2F	VL	H	H	270-480	5,400	warning
mevinphos (DuPont)	Phosdrin	4EC, 10.3WS	H	H	H	3-12	4-90	danger
mexacarbate (Rhone-Poulenc)	Zectran	2E, 25W	-	H	-	24	...	warning danger
MGK-R11 (McLaughlin-Gormley-King)	...	repellent	-	-	-	2,500	...	caution
MGK-R326 (McLaughlin-Gormley-King)	...	repellent	-	-	-	5,230-7,230	...	caution
miral (CIBA-Geigy)	Triumph	EC	H	H	H	40-60	118-3,100	warning
monocrotophos (CIBA-Geigy, DuPont)	Azodrin	5M	H	H	-	14	336	danger
naled (Chevron)	Dibrom	8E, oil	H	H	L	430	1,100	danger
nicotine (Black Leaf)	Black Leaf 40, others	40S	-	-	L	50-60	50	danger
Nosema locustae (Reuter)	Grasshopper spore	WP, bait	EL	EL	EL	NT	NT	caution

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b]			Acute LD_{50}[c]		Signal word
			Fish	Bee	Bird	Oral	Dermal	
oxamyl (DuPont)	Vydate	2L	-	M	-	5	710	danger
oxydemeton-methyl (Mobay)	Metasystox-R	2E	VH	M	M	65-80	250	warning
oxythioquinox (Mobay)	Morestan	25WP	-	L	-	2,500-3,000	>500	caution
paradichlorobenzene (PPG-Industries)	PDB	fumigant (crystals, liquid)	-	-	-	500	2,000	warning
parathion (Mobay, Monsanto)	several	EC, WP, D, oils	H	H	H	4-13	7-21	danger
permethrin (FMC, ICI)	Ambush, Atroban, Dragnet, Ectiban, Expar, Insectrin, Overtime, Permaban, Permectrin, Pounce, Pramex, Torpedo	many	VH	H	L	430-4,000	>2,000	warning danger
phorate (Am. Cyanamid)	Thimet, Aastar	20G	VH	M	M	2-4	2-6	danger
phosalone (Rhone-Poulenc)	Zolone	3EC, 25WP	H	M	-	120-170	1,500	warning
phosmet (ICI)	Imidan, Prolate	50WP	H	H	L	113	>5,000	warning
phosphamidon (CIBA-Geigy)	Dimecron	8L, soluble concentrates	L	H	VH	17	374	danger
piperonyl butoxide (Fairfield Am., Prentiss)	...	synergist	VH	-	-	7,500	>7,950	caution
pirimiphos-methyl (ICI)	Actellic, Tomahawk	EC, ear tags	-	-	-	2,050	>2,000	caution
propargite (Uniroyal)	Comite, Omite	6.55EC, 6E, 30W	H	L	L	220	>300	danger
propetamphos (Sandoz)	Safrotin	EC, WP	-	-	-	119	2,825	caution
propoxur (Mobay)	Baygon, others	1.5E, 2% bait, 70WP	-	H	L	90-128	800-1,000	warning
pyrethrum (Fairfield Am., Prentiss)	...	flower extract	H	L	VL	1,500	>1,800	caution
resmethrin (Fairfield Am.)	Premgard, Respond, Scourge, Synthrin	many	VH	H	VL	>2,500	3,000	caution
rotenone (Fairfield Am. Prentiss)	Derris, others	many	VH	L	L	132-1,500	1,000-3,000	caution
sulprofos (Mobay)	Bolstar	EC	-	-	-	304	>1,200	warning
tefluthrin	Force	1.5G	VH	-	-	22-35	148-1,480	...
temephos (Am. Cyanamid)	Abate, Ecopro	4E, G	L	M	M	8,600-13,000	>4,000	caution

INSECTICIDE FORMULATIONS AND TOXICITIES

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
terbufos (Am. Cyanamid)	Counter	15G	H	M	H	2-5	7	danger
tetrachlorvinphos (DuPont, SDS Biotech)	Rabon	50WP, 75WP, 3D, EC	-	H	VL	4,000-5,000	>2,500	caution
tetradifon (Duphar)	Tedion	EC, WP, smokes	M	L	VL	>14,700	>10,000	caution
tetramethrin (Fairfield Am.)	Neo-Pynamin, Phthalthrin	25EC	-	-	-	>5,000	>5,000	caution
thiodicarb (Monsanto, Rhone-Poulenc)	Larvin	3.2F	-	M	-	66	>2,000	warning
tralomethrin (Am. Hoechst)	Scout	EC	VH	-	L	99-3,000	>2,000	caution
trichlorfon (Mobay, NOR-AM, Tuco)	Anthon, Combot, Dipterex, Dylox, Equibot, Neguvon, Proxol, others	many	L	L	M	560-630	>2,000	warning
trimethacarb (Rhone-Poulenc)	Broot	15GX	-	M	-	178-232	>2,000	caution

[a]Formulations: D, dust; E, EC, emulsifiable concentrate; F, flowable; G, granules; L, liquid solution; LC, liquid concentrate; LV, low volume; M, miscible; RTU, ready to use; S, solution; SL, slurry; SP, soluble powder; ULV, ultra low volume; W, WP, wettable powder; WD, water dispersion; WS, water soluble; XLR, extra long residual.
[b]Toxicity to fish, bees, and birds: L, low; M, moderate; H, high; EL, extremely low; VH, very high; VL, very low.
[c]LD_{50} - based on technical grade, not formulated product.
[d]AV - acute vapor (1 hr); CV - chronic vapor (40 hr).
[e]NT- no evidence of acute or chronic toxicity to mammals.

WEEDS

WEEDS

1990 Weed Control for Corn, Soybeans, and Sorghum

This guide is based on the results of research conducted by the University of Illinois Agricultural Experiment Station, other experiment stations, and the United States Department of Agriculture (USDA). Consideration has been given to the soils, crops, and weed problems of Illinois.

The user must have an understanding of the benefits and risks associated with cultural weed control methods such as primary tillage, row cultivation, and rotary hoeing. Since these practices change little from year to year, the majority of this text will focus on helping make practical, economical, and environmentally sound decisions regarding herbicide use.

Precautions

When selecting a weed control option, consider not only the benefit of controlling the weeds, but the risks involved in using a herbicide. Risks can be reduced by observing the following precautions.

- Apply herbicides only to those crops for which use has been approved.
- Clean tanks thoroughly when changing herbicides, especially when using a postemergence herbicide. Use a 1-percent ammonia wash to clean any traces of 2,4-D or dicamba from the tank before spraying soybeans. Some herbicide labels provide cleaning suggestions.
- Correctly calibrate the sprayer, and check the nozzle output and adjustment before adding the herbicide.
- Use recommended rates. Applying too much herbicide is costly and, in addition, can damage crops and cause illegal residues. Using too little herbicide can result in poor weed control.
- Apply herbicides only at times specified on the label. Observe the recommended intervals between treatment and pasturing or between treatment and harvesting of crops, as well as recommended intervals between application and subsequent planting of crops.
- Guard against drift injury to nearby susceptible plants, such as ornamentals and vegetables, as well as agronomic crops. Mist or vapors from 2,4-D and dicamba sprays may drift several hundred yards. Whenever possible, operate sprayers at low pressure with tips that deliver large droplets. Spray only on calm days or make sure that the wind is not moving toward susceptible crop plants and ornamentals. Use special precaution with Command.
- Avoid applying a herbicide to a crop that is under stress or predisposed to injury. Under certain conditions some herbicides may damage the crop when environmental conditions reduce the plant's ability to resist injury.
- Avoid planting a susceptible crop in a field where herbicide carryover is likely. This typically occurs in the year following a very dry year.
- Applicators should use appropriate precautions to protect themselves and others from exposure to herbicides.
- Be sure that animals or persons not directly involved in the operation are not present in the area. Use special precautions near residential areas.
- Several herbicide labels carry the following groundwater warnings under either the environmental hazard or the groundwater advisory section. "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN • COLLEGE OF AGRICULTURE • COOPERATIVE EXTENSION SERVICE

Urbana, Illinois Circular 1277-90 (revised annually) October 1989

permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface."

- Check the herbicide label for the proper method of container disposal. Triple rinse, puncture, and haul metal containers to an approved sanitary landfill. Haul paper containers to a sanitary landfill, or burn them in an approved manner.
- Promptly return unused herbicides to a safe storage place. Store them in the original containers away from unauthorized persons, particularly children.
- Because formulations and labels are sometimes changed and government regulations modified, always refer to the most recent product label.

This guide has been developed to help you use herbicides as effectively and safely as possible. Because no guide can remove all the risk involved, however, the University of Illinois and its employees assume no responsibility for the results of using herbicides, even if they have been used according to the suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Cultural and mechanical control

Good cultural practices that aid in weed control include adequate seedbed preparation, adequate fertilization, crop rotation, planting on the proper date, use of the optimum row width, and seeding at the rate required for optimum stands.

Planting in relatively warm soil can help the crop emerge quickly and compete better with weeds. Good weed control during the first 3 to 5 weeks is extremely important for both corn and soybeans. If weed control is adequate during that period, corn and soybeans will usually compete quite well with most of the weeds that begin growing later.

Narrow rows will shade the centers faster and help the crop compete better with the weeds. If herbicides alone cannot give adequate weed control, however, then keep rows wide enough to allow for cultivation. Some of the newer herbicides are improving the chances of achieving adequate control without cultivation.

If a preemergence or preplant herbicide does not appear to be controlling weeds adequately, use the rotary hoe while weeds are still small enough to be controlled. Use the rotary hoe after weed seeds have germinated but before most weeds have emerged. Operate it at 8 to 12 miles per hour, and weight it enough to stir the soil and kill the tiny weeds. Rotary hoeing also aids crop emergence if the soil is crusted.

Row cultivators also should be used while weeds are small. Throwing soil into the row can help smother small weeds. Cultivate shallowly to prevent injury to crop roots.

Herbicides can provide a convenient and economical means of early weed control and allow for delayed and faster cultivation. Furthermore, unless the soil is crusted, it may not be necessary to cultivate some fields if herbicides are controlling weeds adequately.

Herbicide incorporation

Soil-applied herbicides are incorporated to minimize surface loss, reduce dependence upon rainfall, and provide appropriate placement of the herbicide. Herbicides such as Sutan+ and Eradicane are incorporated soon after application to minimize surface loss from volatilization. Treflan and Sonalan are incorporated to minimize loss due to photodecomposition and volatilization. Triazine herbicides such as atrazine and Bladex and acetamide herbicides such as Lasso and Dual may be incorporated to minimize dependence upon timely rainfall; but because these herbicides are not lost as quickly from the soil surface, the timing of incorporation is less critical.

Incorporation should place the herbicide uniformly throughout the top 1 or 2 inches of soil for the best control of small-seeded annual weeds that germinate at shallow depths. Slightly deeper placement may improve the control of certain weeds from deep-germinating seed under relatively dry conditions. Incorporating too deeply, however, tends to dilute the herbicide and may reduce the effectiveness. The field cultivator and tandem disk place most of the herbicide at about one-half the depth of operation. Thus for most herbicides, the suggested depth of operation is 3 to 4 inches.

Thorough incorporation with ground-driven implements requires two passes. Single-pass incorporation can result in streaked weed control, especially in moist soils. It can also cause concentrated zones of herbicide, which are conducive to crop injury. Single-pass incorporation may be adequate with some herbicides that tend to move laterally in the soil. It may also be adequate with some equipment, especially if rotary hoeing, cultivation, or subsequent herbicide treatments are used to improve weed control. If the first pass sufficiently covers the herbicide to prevent surface loss, the second pass can be delayed until immediately before planting.

The depth and thoroughness of incorporation depend upon the type of equipment used, the depth and speed of operation, the texture of the soil, and the amount of soil moisture. Field cultivators and tandem disks are commonly used for incorporation; however, disk-chisels and other combination tools are being used in some areas.

Field cultivators

Field cultivators are frequently used for herbicide incorporation. They should have three or more rows of shanks with an effective shank spacing of no more than 8 to 9 inches (a spacing of 24 to 27 inches on each of three rows). The shanks may be equipped with points or sweeps. Sweeps usually give better incorporation, especially when soil conditions are a little too wet or dry for optimum soil flow and mixing. Sweeps for C-shank cultivators should be at least as wide as the effective shank spacing.

The recommended operating depth for the field cultivator is 3 to 4 inches. It is usually sufficient to operate the field cultivator only deep enough to remove tractor tire depressions. The ground speed should be at least 6 miles per hour. The field cultivator must be operated in a level position so that the back shanks are not operating in untreated soil, which would result in streaked weed control. Two passes are recommended to obtain uniform weed control. If single-pass incorporation is preferred, the use of wider sweeps or narrower spacing with a 3- to 5-bar harrow or rolling baskets pulled behind will increase the probability of obtaining adequate weed control.

Tandem disks

Tandem disk harrows invert the soil and usually place the herbicide deeper in the soil than most other incorporation tools. Tandem disks used for herbicide incorporation should have disk blade diameters of 20 inches or less and blade spacings of 7 to 9 inches. Larger disks are considered primary tillage tools and should not be used for incorporating herbicides. Spherical disk blades give better herbicide mixing than do conical disk blades.

Tandem disks usually place most of the herbicide in the top 50 to 60 percent of the operating depth. For most herbicides, the suggested operating depth is from 3 to 4 inches. Two passes are recommended to obtain uniform mixing with a double disk. A leveling device (harrow or rolling baskets) should be used behind the disk to obtain proper mixing. Recommended ground speeds are usually between 4 and 6 miles per hour. The speed should be sufficient to move the soil the full width of the blade spacing. Lower speeds can result in herbicide streaking.

Combination tools

Several new tillage tools combine disk gangs, field cultivator shanks, and leveling devices. Many of these combination tools can handle large amounts of surface residue without clogging and yet leave considerable crop residue on the soil surface for erosion control. Results indicate that these combination tools may provide more uniform one-pass incorporation than does a disk or field cultivator, but one pass with them is generally no better than two passes with the disk or field cultivator.

Chemical weed control

Plan your weed-control program to fit your soils, tillage program, crops, weed problems, and farming operations. Good herbicide performance depends on the weather and on wise selection and application. Your decisions about herbicide use should be based on the nature and seriousness of your weed problems. The herbicide selectivity tables at the end of this guide indicate the susceptibility of our most common weed species to herbicides.

Corn or soybeans may occasionally be injured by some of the herbicides registered for use on these crops. To reduce injury to crops, apply the herbicide uniformly, at the time specified on the label, and at the correct rate. (See the section entitled "Herbicide rates.") Crop tolerance ratings for various herbicides are also given in the tables at the end of this guide. Unfavorable conditions such as cool, wet weather, delayed crop emergence, deep planting, seedling diseases, soil in poor physical condition, and poor-quality seed may contribute to crop stress and herbicide injury. Hybrids and varieties also vary in their tolerance to herbicides and environmental stress factors. Once injured by a herbicide, plants are prone to disease.

Crop planting intentions for next season must also be considered. Where atrazine or simazine are used, you should not plant spring-seeded small grains, small-seeded legumes and grasses, or vegetables the following year. Be sure that the application of Treflan or similar herbicides for soybeans is uniform and sufficiently early to reduce the risk of injury to wheat or corn following soybeans. Note that certain cropping restrictions apply for Command, Scepter, Classic, Canopy, Preview, and Lorox Plus. Refer to the herbicide label for information about cropping sequence and appropriate intervals to allow between different crops.

Some herbicides have different formulations and concentrations under the same trade name. *No endorsement of any trade name is implied, nor is discrimination against similar products intended.*

Herbicide combinations

Herbicide combinations can control more weed species, reduce carryover, or reduce crop injury. Numerous combinations of herbicides are sold as premixes, while others are tank-mixed. Registered tank-mixes are shown in Tables 2, 7, and 10. Tank-mixing allows you to adjust the ratio of herbicides to fit local weed and soil conditions, while premixes may overcome some of the compatability problems found with tank-mixing. When using a tank-mix, you must follow restrictions on all products used in the combination.

Problems may occur when mixing emulsifiable concentrate (EC) formulations with wettable powder (W), liquid flowable (L), or dry flowable (DF) formulations. These problems can sometimes be prevented by using proper mixing procedures. If using liquid fertilizers, check compatibility in a small lot before mixing a tankful. Fill tanks at least one-fourth full with water or liquid fertilizer before adding herbicides that are suspended. The addition of compatibility agents may be necessary. Wettable powders, DF's, or L's should be

Table 1. Herbicide and Herbicide Premix Names and Restrictions

Trade name	Common (generic) name(s)	RUP	GWA	Key word
AAtrex, atrazine	atrazine	–	+	Caution
Ala-Scept	alachlor + imazaquin	+	+	Danger
Amiben	chloramben	–	–	Caution
Assure	quizalofop	–	–	Caution
Banvel	dicamba	–	–	Warning
Basagran	bentazon	–	–	Caution
Bicep	metolachlor + atrazine	–	+	Caution
Bladex	cyanazine	+	+	Warning
Blazer	acifluorfen	–	–	Danger
Bronco	alachlor + glyphosate	+	+	Danger
Buctril	bromoxynil	+	–	Warning
Buctril/atrazine	bromoxynil + atrazine	+	+	Caution
Bullet	alachlor + atrazine	+	+	Caution
Butyrac 200	2,4-DB	–	–	Danger
Cannon	alachlor + trifluralin	+	+	Warning
Canopy	metribuzin + chlorimuron	–	+	Caution
Classic	chlorimuron	–	–	Caution
Cobra	lactofen	–	–	Danger
Command	clomazone	–	–	Warning
Commence	clomazone + trifluralin	–	–	Danger
Dual	metolachlor	–	+	Caution
Eradicane	EPTC + safener	–	–	Caution
Eradicane Extra	EPTC + extender	–	–	Caution
Evik	ametryn	–	–	Caution
Extrazine	cyanazine + atrazine	+	+	Warning
Freedom	alachlor + trifluralin	+	+	Warning
Fusilade 2000	fluazifop	–	–	Caution
Galaxy	bentazon + acifluorfen	–	–	Danger
Genate Plus	butylate + safener	–	–	Caution
Gramoxone Extra	paraquat	+	–	Danger
Laddok	bentazon + atrazine	–	+	Danger
Lariat	alachlor + atrazine	+	+	Warning
Lasso EC	alachlor	+	+	Danger
Lasso MT	alachlor	+	+	Caution
Lexone	metribuzin	–	+	Caution
Lorox, Linex	linuron	–	–	Caution
Lorox Plus	linuron + chlorimuron	–	–	Warning
Marksman	dicamba + atrazine	–	?	Caution
Many trade names	2,4-D dimethylamine	–	–	Danger
Many trade names	2,4-D ester	–	–	Caution
Option	fenoxaprop	–	–	Warning
Passport	trifluralin + imazethapyr	–	–	Danger
Poast, Poast Plus	sethoxydim	–	–	Warning
Preview	metribuzin + chlorimuron	–	+	Caution
Princep, Simazine	simazine	–	+	Caution
Prowl	pendimethalin	–	–	Warning
Pursuit	imazethapyr	–	–	Caution
Pursuit Plus	pendimethalin + imazethapyr	–	–	Caution
Reflex	fomesafen	–	–	Warning
Rescue	naptalam + 2,4-DB	–	–	Warning
Roundup	glyphosate	–	–	Warning
Salute	metribuzin + trifluralin	–	+	Caution
Scepter	imazaquin	–	–	Caution
Sencor	metribuzin	–	+	Caution
Sonalan	ethalfluralin	–	–	Warning
Squadron	imazaquin + pendimethalin	–	–	Danger
Storm	bentazon + acifluorfen	–	–	Danger
Sutan+	butylate + safener	–	–	Caution
Sutazine	butylate + atrazine	–	?	Danger
Tackle	acifluorfen	–	–	Danger
Tandem	tridiphane	–	–	Warning
Treflan/Trifluralin	trifluralin	–	–	Warning
Tri-Scept	imazaquin + trifluralin	–	–	Danger
Turbo	metribuzin + metolachlor	–	+	Caution

Note: RUP = restricted-use pesticide to be applied by licensed applicator; GWA = ground water advisory; ? = contains atrazine but has no GWA; and key word = toxicity signal, indicates need for extra precautions. The key words "Danger" and "Warning" often indicate pesticides that can irritate skin and eyes, necessitating protective clothing, gloves, and goggles or face shield.

added to the tank and thoroughly mixed before adding ECs. Emulsify ECs by mixing with equal volumes of water before adding them to the tank. Empty and clean spray tanks often enough to prevent accumulation of material on the sides and the bottom of the tank.

The user can apply two treatments of the same herbicide (split application) or can use two different herbicides, provided such uses are registered. The use of one herbicide after another is referred to as a sequential or overlay treatment.

Herbicide rates

Herbicide rates vary according to the time of application, soil conditions, the tillage system used, and the seriousness of the weed infestation. Rates of individual components of a combination are usually lower than rates for the same herbicides used alone.

The rates for soil-applied herbicides usually vary with the texture of the soil and the amount of organic matter the soil contains. For instance, medium-textured soils that have little organic matter require lower rates of most herbicides than do fine-textured soils that have medium to high organic-matter content. For sandy soils, the herbicide label may specify "do not use," "use a reduced rate," or "use a postemergence rather than soil-applied herbicide," depending on the herbicide and its adaptation and on crop tolerance. Postemergence rates often vary depending upon the size and species of the weeds and whether or not an adjuvant is specified.

The rates given in this guide are, unless otherwise specified, broadcast rates for the amount of formulated product. If you plan to band or direct herbicides, adjust the amount per crop acre according to the percent of the area actually treated. Many herbicides have several formulations with different concentrations of active ingredient. Be sure to read the label and make necessary adjustments when changing formulations.

Postemergence herbicide principles

Postemergence herbicides applied to growing weeds generally have foliar rather than soil action; however, some may have both. The rates and timing of applications are based on weed size and climatic conditions. Weeds can usually be controlled with a lower application rate when they are small and tender. Larger weeds often require a higher herbicide rate or the addition of a spray additive, especially if the weeds have developed under droughty conditions. Herbicide penetration and action are usually greater with warm temperature and high relative humidity. Rainfall occurring too soon after application (1 to 8 hours, depending on the herbicide) can cause poor weed control.

Translocated herbicides are most effective at lower spray volumes (5 to 20 gallons per acre), whereas contact herbicides require more complete coverage. Foliar coverage increases as water volume and spray pressure are increased. Spray nozzles that produce small droplets also improve coverage. For contact herbicides, 20 to 40 gallons of water per acre are often recommended for ground application, and a minimum of 5 gallons per acre is recommended for aerial application. Spray pressures of 30 to 60 psi are often suggested with flat-fan or hollow-cone nozzles to produce small droplets and improve canopy penetration. These small droplets are quite subject to drift.

The use of an adjuvant such as a surfactant, crop oil concentrate, or fertilizer solution may be recommended to improve spray coverage and herbicide uptake. These spray additives will usually improve weed control but may increase crop injury. Spray additives may be needed, especially under droughty conditions or on larger weeds.

Crop size limitations may be specified on the label to minimize crop injury and maximize weed control. If weeds are smaller than the crop, basal-directed sprays may minimize crop injury because they place more herbicide on the weeds than on the crop. If the weeds are taller than the crop, rope-wick applicators or recirculating sprayers may be used to place the herbicide on the top of the weeds and minimize contact with the crop. Follow the label directions and precautions for each herbicide.

Conservation tillage and weed control

Conservation tillage allows crop production while it reduces soil erosion by protecting the soil surface with plant residue. Minimum or reduced tillage refers to any tillage system that leaves crop residue on the soil surface. These include primary tillage with chisel plows or disks and the use of field cultivators, disks, or combination tools for secondary tillage. Mulch tillage is reduced tillage which leaves at least 30 percent of the soil surface covered with plant residue.

Ridge tillage and zero tillage are conservation tillage systems with no major tillage prior to planting. In ridge tillage, conditions are often ideal for banding of preemergence herbicides. Cultivation is a part of the system. "No-till" is actually slot tillage for planting with no overall primary tillage. No-till planting conserves moisture, soil, and fuel. It also allows timely planting of soybeans or sorghum after winter wheat harvest.

The elimination of tillage prior to planting means existing vegetation must be controlled with herbicides. The elimination or reduction of herbicide incorporation and row cultivation puts a greater stress and reliance on chemical weed control. Soil conditions must be ideal for single-pass herbicide incorporation to be uniform. Greater emphasis may be placed on preplant or postplant soil-applied herbicides which are not incorporated or foliar-applied (postemergence) herbicides.

Where primary tillage is minimized, soil residual herbicides applied several weeks before planting may reduce the need for a "knockdown" herbicide. However, early preplant (EPP) application may require additional herbicides (preemergence or postemergence) or cultivation for satisfactory weed control after planting. See the corn and soybean sections entitled "Preplant not incorporated" for more information.

Corn and soybeans are the primary crops in Illinois, and they are often planted in a corn and soybean rotation. Modern equipment allows successful no-till planting in corn or soybean stubble. The use of a disk or chisel plow on corn stubble may still provide adequate crop residue to allow minimum tillage. Herbicides are also available to allow a "total postemergence" weed control program, especially for soybeans.

Soybean stubble is often ideal for zero or minimum tillage. Primary tillage is rarely needed and the crop residue should not interfere with herbicide distribution. Early preplant application of preemergence herbicides or the use of postemergence herbicides can often provide adequate weed control.

The existing vegetation in corn and soybean stubble is often annual weeds. If the weeds are small, they can often be controlled prior to planting with herbicides that have both foliar and soil residual activity. For corn, these include atrazine or Bladex and their premixes. For soybeans, metribuzin (Sencor or Lexone), linuron (Lorox), and their premixes with chlorimuron (Preview, Canopy, or Lorox Plus), as well as Pursuit can be used. Foliar activity is enhanced with the addition of crop oil or surfactant.

Sod planting requires a different approach. If minimum or zero-tillage is to be used in perennial grass or legume sods, the sod should be controlled prior to planting. Late control of sod may deplete soil moisture, making crop establishment difficult when soil moisture is low. Some grass sods may require the use of Roundup *in the fall* when there is adequate foliage and translocation for effective control. Bluegrass or clover may be controlled by atrazine alone or combined with Bladex. Clover sods can be controlled by Banvel or 2,4-D applied in the fall (soybeans or corn) or in the spring (corn only) before planting. Alfalfa control usually requires Banvel plus 2,4-D. *Do not plan to take a spring cutting before planting into forage sods.* Regrowth rarely provides sufficient foliage for active herbicide uptake and kill of the sod prior to planting of corn.

Winter cover crops of wheat or rye can be controlled by Roundup prior to planting corn or soybeans, or Gramoxone plus atrazine may be used prior to planting corn.

Annual vegetation over 2 to 3 inches tall at planting time will require a burndown or translocated herbicide. Gramoxone, Roundup, or Bronco can be used with most preemergence herbicides to control existing vegetation.

Gramoxone Extra or Super (paraquat) can be used to control existing vegetation prior to planting. Gramoxone Extra **2.5S** is used at 1.5 to 3 pints per acre. The older Gramoxone Super **1.5S** was used at 1.5 to 2.5 pints per acre, the new 2.5S formulation provides more paraquat per pint and per acre than the older 1.5S. Gramoxone should be applied with a nonionic surfactant in at least 40 gallons of spray per acre. Gramoxone alone often fails to provide adequate control of smartweed, giant ragweed, "marestail" and fall panicum. *Gramoxone is a restricted-use pesticide.*

Roundup (glyphosate) can be used at 3 to 8 pints per acre to control existing vegetation prior to planting. Roundup at the higher rates can translocate to the roots to control some perennials. Spray volume per acre should be 20 to 40 gallons. Small annual weeds can be controlled with 0.75 to 1 pint of Roundup in 5 to 10 gallons of water per acre plus 0.5-percent nonionic surfactant. Do not mix Roundup with Lasso Micro Tech or Bullet.

Bronco (glyphosate plus alachlor) contains the equivalent of 2.6 quarts of Lasso EC and and 1.4 quarts of Roundup per gallon. Bronco is used at 3 to 5 quarts per acre applied in 10 to 30 gallons of water. Application can also be made in UAN nitrogen solutions if annual weeds are less than 6 inches tall. *Bronco is a restricted-use pesticide.*

Banvel (dicamba) may be used in the fall or spring before planting corn or in the fall (*not in the spring*) before planting soybeans. Banvel can control annual and some perennial broadleaved plants including clovers and alfalfa. A combination of Banvel plus 2,4-D can often control more weeds at lower costs.

2,4-D can be used in the fall or spring before planting corn to control broadleaved weeds. The status of 2,4-D prior to planting soybeans is somewhat controversial. See the "preplant not incorporated" portion in the soybean section.

Herbicides for corn

Herbicides mentioned in this section are registered for use on field corn. Some are also registered for silage corn. See Table 2 for registered combinations. Herbicide suggestions for sweet corn and popcorn may be found in Circular 907, *1990 Weed Management Guide for Commercial Vegetable Growers,* which appears in the *1990 Illinois Pest Control Handbook.* Growers producing hybrid seed corn should check with the contracting company or the producer of inbred-seed about tolerance of the parent lines. See Tables 3 and 4 for weeds controlled by the herbicides used in corn.

Preplant not incorporated (corn)

Interest in early preplant application is increasing, especially with the trend toward reduced tillage. Bladex, Banvel, and atrazine have postemergence as well as residual activity. Early weeds such as smartweed can be controlled while they are small, and emergence of other weeds can be curtailed.

Table 2. Registered Herbicide Combinations for Preplant Incorporated (PPI), Preemergence (Pre), or Early Postemergence (EPoE) Application in Corn

	Atrazine	Bladex	Extrazine II	Atrazine + Princep
PPI only				
Eradicane	1	1	1	—
Genate Plus	1	1	1	—
Sutan +	1	1	1	—
PPI or Pre or EPoE				
Used alone	1,2,3	1,2,3	1,2,3	1,2
Dual	1,2,3	1,2	1,2	1,2
Lasso	1,2,3	1,2	1,2	1,2
Prowl	2,3	2,3	-	-

1 = Preplant incorporated
2 = Preemergence
3 = Early postemergence
— = Not registered

With **AAtrex, Dual,** or **Bicep,** preplant surface application may be made using a two-thirds rate as early as 45 days before planting, followed by a one-third rate at planting. A single full-rate application may be made within 30 days before planting. The rates are 4 to 6 pints per ace of AAtrex, 2.5 to 3 pints per acre of Dual, and 4.8 to 7.5 pints per acre of Bicep.

Lariat and Bullet (alachlor plus atrazine) may be used as a preplant plus preemergence 60/40-percent split application on medium- to fine-textured soils. The preplant application may be made up to 45 days before planting. Lariat may also be applied as a single application up to 30 days before planting. *Products containing alachlor are classified as restricted-use pesticides.*

Bladex may be applied early preplant at labeled rates; but if Bladex is applied earlier than 15 days before planting, a split application or use of another herbicide at or after planting is suggested. **Extrazine II** may also be applied 15 to 30 days before planting corn. *These products are restricted-use pesticides.*

Banvel (dicamba) applied before planting no-till corn can control emerged and actively growing broadleaf weeds. Use one pint per acre for medium- and fine-textured soils and one-half pint on coarse soils with over 2-percent organic matter.

Marksman (dicamba plus atrazine) may be used as a preplant treatment in no-till corn. The rate is 3.5 pints per acre on medium- and fine-textured soils that have at least 2-percent organic matter. See the postemergence section for more information.

2,4-D may be used to control existing vegetation in minimum-tillage and no-till situations before planting corn. Many preplant tank-mix labels allow for 1 to 2 pints of 2,4-D LV ester per acre. See the specific label for details.

Buctril, or a tank-mix or premix of Buctril plus atrazine, may be used before planting field corn or grain sorghum, up until just before crop emergence to control emerged annual broadleaf weeds. Apply Buctril alone at 1.0 to 1.5 pints per acre, or Buctril mixed with atrazine at 0.5 to 1.2 pounds of active ingredient. *Buctril is a restricted-use pesticide.*

Roundup may be used preplant to corn or sorghum at three-fourths to one pint (12 to 16 fluid ounces) per acre to control small annual weeds. Use 5 to 10 gallons of water per acre plus a nonionic surfactant. Roundup may be mixed with Banvel or 2,4-D.

Preplant incorporated herbicides (corn)

Some herbicides may be applied prior to planting and incorporated. The time of application will depend upon the label directions and field conditions. Herbicides with sufficient residual activity may be applied

Table 3. Corn Herbicides: Grass and Nutsedge Control

Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	WPM	YNS	CRN
Soil-applied											
Atrazine	8	5	3	7	8	4	7	2	3	5	0
Bladex	7	7	8	8	8	6	6	2	6	3	2
Dual	8+	9	8+	9	9	7	7	6	7	7+	2
Eradicane	9	8	9	9	9	7	8	6	7	7	1+
Eradicane Extra	9	9	9	9	9	8	9	8	8+	8	2
Lasso	8+	9	8	9	9	7	7	5	7	7	2
Marksman	4	3	2	3	3	2	1	1	1	4	2+
Princep	8	6	5	7	7	4	5	4	4	2	0
Prowl	8	8	8	8	8	7	7	6	7	0	2+
Sutan+	9	9	9	9	9	8	9	7	7	7	1
Foliar-applied											
Atrazine/oil	8	5	5	7	7	6	7	2	4	6	1+
Bladex	8	7	7	8	8	5	7	2	6	5	1+
Buctril	0	0	0	0	0	0	0	0	0	2	1+
Buctril/atrazine	2	2	0	3	3	0	0	0	0	5	1+
Laddok	2	2	0	3	3	0	2	0	0	8	1
Marksman	2	2	0	2	2	2	2	1	0	3	1+
Tandem/atrazine	9	8	6	8	7	7	7	3	7	6	1+
Tandem/Bladex	9	8	7	8	8	7	7	2	7	5	2+

Note: BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, WPM = wild proso millet, YNS = yellow nutsedge, and CRN = corn response.

Table 4. Corn Herbicides: Broadleaf Weed Control

Herbicide	AMG	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	VLV
Soil-applied											
Atrazine	9	9	10	9	9	9	9	8	9	8	8
Bladex	8	8	8	9	8	6	9	7	9	7	7
Dual	0	0	4	6	7+	8	5	2	5	0	0
Eradicane	4	2	2	7	4	7	4	3	4	0	5
Lasso	0	0	5	7	7+	9	6	2	5	0	0
Marksman	8	8	8	8	8	9	9	8	9	8	7+
Princep	9	9	9	9	9	9	9	7	9	8	7
Prowl	0	0	2	8	0	9	2	0	3	0	4
Sutan+	4	2	2	4	2	7	4	3	3	0	4
Foliar-applied											
Atrazine/oil	9	9	9	9	9	10	9	8	10	9	9
Banvel	9	9	9	9	8	9	9	9	10	8	7
Bladex	7	8	8	9	9	7	9	7	9	7	7
Buctril	8	9	9	9	9	7+	9	8	8+	9	8
Buctril/atrazine	9	9	10	10	10	10	9	9	10	10	9
2,4-D	9	9	7	9	7	9	9	9	6	8	8
Laddok	8	9	10	9	9	9	9	9	10	10	9
Marksman	9	9	10	10	10	10	9	9	10	9	9
Tandem/atrazine	9	9	9	9	9	10	9	8	10	9	9

Note: AMG = annual morningglory, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, and VLV = velvetleaf.

Rating Scale and Approximate Weed Control

10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, and 6 = 55 to 65%.
Weed control of 5 or less is rarely significant.
Corn injury of 1 or less is rarely significant.
For ratings on herbicide combinations (tank-mix or premix), see the component parts.

Premix:	Grass	+	Broadleaf
Bicep:	Dual	+	atrazine
Bullet:	Lasso	+	atrazine
Extrazine:	Bladex	+	atrazine
Lariat:	Lasso	+	atrazine
Sutazine	Sutan+	+	atrazine

Premix:	Broadleaf	+	Broadleaf
Buctril/atrazine	Buctril	+	atrazine
Laddok	Basagran	+	atrazine
Marksman	Banvel	+	atrazine

early preplant. If these herbicides are applied too early, however, weed control may not last as long as desired after planting. Incorporation should distribute the herbicide uniformly throughout about the top 2 inches of soil. *Do not apply preplant herbicides too early or incorporate them too deeply.*

Sutan+, Genate Plus (butylate), Eradicane, and Eradicane Extra (EPTC) contain crop safening agents. Crop injury is unlikely but may occur when growing conditions are unfavorable or when certain hybrids are used. Eradicane Extra also contains an extender to lengthen weed control. These herbicides control annual grass weeds and at higher rates can control or suppress some problem grasses. The rate for Sutan+, Genate Plus, and Eradicane 6.7E is 4¾ to 7⅓ pints per acre. The rate for Eradicane Extra 6E is 5⅓ to 8 pints per acre. Use the higher rates for heavy infestations of shattercane and yellow nutsedge and for johnsongrass.

Application close to planting time is generally preferred to provide the maximum duration of weed control. These herbicides should be incorporated into the soil soon after application, although 4 hours may elapse before incorporation with the high rate and a dry soil.

Sutan+, Genate Plus, Eradicane, or Eradicane Extra may be tank-mixed with atrazine, Bladex, or Extrazine II to improve broadleaf control. The atrazine rate is 2 to 3 pints of 4L or equivalent amounts of 80W or 90WDG per acre. The Bladex rate is 3 to 4 pints of 4L or 2 to 2½ pounds of 80W per acre. The Extrazine II rate is 4 to 6½ pints per acre.

Sutazine 6ME (butylate plus atrazine) contains 4.8 pounds of butylate and 1.2 pounds of atrazine per gallon. The rate is 5.5 to 10.5 pints per acre.

Preplant or preemergence herbicides (corn)

Except for Prowl, the following herbicides may be incorporated. If mechanical incorporation is used, it should be shallow but thorough.

AAtrex, Atrazine (atrazine), or Princep (simazine) may be applied anytime during the 2 weeks before planting or soon after planting. If rainfall is limited, incorporation may aid performance. Corn tolerance to atrazine and simazine is good, but carryover to subsequent crops may occur.

Princep controls fall panicum and crabgrass better than atrazine but is less effective in controlling cocklebur, velvetleaf, and yellow nutsedge. Princep is more persistent than atrazine and less soluble; thus Princep is usually applied preplant. Princep plus atrazine may

Table 5. Soybean Soil-Applied Herbicides: Grass and Nutsedge Control

Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	VCN	YNS
Soil-applied "grass"										
Command	9	9	9	9	9	8	7	7	5	3
Dual	8+	9	8+	9	9	7	7	5	0	7+
Lasso	8+	8	8	9	9	7	7	5	0	7
Prowl	9	9	9	9	9	9	8	8	4	0
Sonalan	9	8	9	9	9	8	8	7	4	0
Trefluralin	9	9	9	9	9	9	8	8	5	0
Soil-applied "broadleaf"										
Amiben	8	7	8	8+	8	6	5	6	3	0
Canopy	6	5	6	6	6	5	5	2	3	3
Lexone	6	5	6	6	6	5	5	2	3	2
Lorox	6	6	6	6	6	6	4	4	3	2
Lorox Plus	6	6	6	6	6	6	4	4	4	2
Preview	6	5	6	6	6	5	5	2	3	2
Pursuit	6	7	7	7	6	6	5	7	5	4
Scepter	6	6	6	6	6	5	5	5	7	6
Sencor	6	5	6	6	6	5	5	2	2	2

Note: BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, and VCN = volunteer corn, and YNS = yellow nutsedge.

Table 6. Soybean Soil-Applied Herbicides: Broadleaf Control

Herbicide	AMG	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	VLV	SBN
Soil-applied "grass"												
Command	0	6	8	9	6	6	8	5	8	4	9+	1
Dual	0	0	4	6	7+	8	5	2	4	0	0	1
Lasso	0	0	5	7	7+	9	6	2	5	0	0	1
Prowl	4	0	2	9	0	9	2	0	4	0	4	1
Sonalan	4	0	2	9	5	9	2	0	4	0	3	2
Trifluralin	4	0	2	9	0	9	2	0	4	0	2	1
Soil-applied "broadleaf"												
Amiben	2	3	5	9	7	9	8	6	8	4	7	1
Canopy	6	9	9	9	6	9	9	7	9	8	9	2
Lexone	3	6	7	9	4	9	8	6	9	7	8	2
Lorox	4	6	5	9	7	9	8	6	9	6	6	2
Lorox Plus	6	8	7	9	7	9	9	7	9	7	7	2
Preview	6	8	9	9	6	9	9	7	9	8	9	2
Pursuit	6	7	8	9	8	9	7	6	9	8	8	1
Scepter	6	9	8	9	8+	9	9	7	9	9	7	1
Sencor	3	6	7	9	4	9	8	6	9	7	8	2

Note: AMG = annual morningglory, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, VLV = velvetleaf, and SBN = soybean tolerance.

Rating Scale and Approximate Weed Control

10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, and 6 = 55 to 65%.
Weed control of 5 or less is rarely significant.
For ratings for combinations (tank-mix and premix), see the component parts.

Premix:	"Grass"	+	"Grass"	Premix:	"Grass"	+	"Broadleaf"
Ala-Scept	Lasso	+	Scepter	Pursuit Plus:	Prowl	+	Pursuit
Cannon:	Lasso	+	Treflan	Salute:	Treflan	+	Sencor
Commence:	Treflan	+	Command	Squadron:	Prowl	+	Scepter
Freedom:	Lasso	+	Treflan	Tri-Scept:	Treflan	+	Scepter
				Turbo:	Dual	+	Sencor
				Passport:	trifluralin	+	Pursuit

be used in 1:1 or 2:1 combinations; the total rate is the same as for atrazine used alone.

The rate for atrazine used alone is 2½ to 3¾ pounds of atrazine 80W, 4 to 6 pints of 4L, or 2.2 to 3.3 pounds of AAtrex Nine-0. Atrazine controls annual broadleaf weeds better than it does grasses, and it is often used at reduced rates in tank-mix combinations to improve broadleaf weed control. The rate for atrazine in some combinations is 1½ to 2 pounds of atrazine 80W, 2 to 3 pints of atrazine 4L, or 1.1 to 1.8 pounds of AAtrex Nine-0. These rates may not provide adequate control of cocklebur, morningglory, and velvetleaf but can reduce the risk of carryover.

You can minimize carryover injury by mixing and applying the herbicides accurately, by applying them early, by using the lowest rates consistent with good weed control, and by tilling the soil to dilute the herbicide. The risk of carryover is greater after a cool, dry season and on soils with a pH over 7.3.

If you use atrazine at more than 3 pounds of active ingredient per acre (lb a.i./A) or if you apply after June 10, plant only corn or sorghum the next year. If you use atrazine in the spring and must replant, then plant only corn or sorghum that year. Do not plant small grains, small-seeded legumes, or vegetables in the fall or the following spring. Soybeans planted the year after an application of atrazine can also be injured, especially if you use herbicides containing metribuzin.

Bladex (cyanazine) has shorter soil persistence than atrazine, but atrazine has better corn tolerance. Rates of Bladex must be selected accurately on the basis of soil texture and organic-matter content to reduce the possibility of corn injury. The rates per acre for Bladex alone are 1.5 to 6.0 pounds of 80W, 1.35 to 5.3 pounds of 90DF, or 1.25 to 4.75 quarts of 4L. You can lessen the risk of corn injury by using reduced rates of Bladex in combination with other herbicides.

Bladex provides better control of most annual grasses than does atrazine but is weaker than atrazine on several broadleaf weeds, particularly pigweed.

Extrazine II contains cyanazine (Bladex) and atrazine. It is available as 90DF and 4L formulations and can be used preplant incorporated, preemergence, or in tank-mix combinations similar to Bladex. (See Table 2.) Rates must be adjusted carefully to the soil texture and organic-matter content.

Bladex may be tank-mixed with Genate Plus, Sutan+, or Eradicane for preplant incorporation or with Lasso or Dual for preplant or preemergence application. *Bladex and Extrazine II are restricted-use pesticides.*

Lasso (alachlor) or Dual (metolachlor) may be preplant incorporated or applied preemergence at planting time. Preplant incorporation of these herbicides can improve control of yellow nutsedge and can lessen dependence upon rainfall. Incorporation should distribute the herbicide evenly throughout the top 2 inches of soil.

Lasso and Dual control annual grasses and help control yellow nutsedge. You can improve broadleaf weed control by using atrazine, Bladex, or both in either a preplant or a preemergence combination.

Lasso may be applied anytime during the week before planting corn and shallowly incorporated, or it may be used after planting but before the crop and weeds emerge and within 5 days after the last tillage operation. The rate is 2 to 4 quarts of Lasso 4E or 16 to 26 pounds of Lasso 15G per acre. Arena, Judge, Stall, Saddle, and Confidence are private brands of alachlor on the market. *Products containing alachlor are classified as restricted-use pesticides.*

Dual may be applied and shallowly incorporated within 45 days before planting, or it may be used soon after planting. The rates are 1½ to 4 pints of Dual 8E or 6 to 16 pounds of Dual 25G per acre.

Lasso or Dual plus atrazine may be preplant incorporated or applied after planting until corn is 5 inches tall and grass weeds have not passed the two-leaf stage. *Do not apply with liquid fertilizer after the crop emerges.* The suggested rate is 1½ to 4 quarts of Lasso or 1¼ to 2½ pints of Dual 8E plus 1½ to 2½ pounds of atrazine 80W, 1 to 2 quarts of atrazine 4L, or 1.1 to 2.2 pounds of AAtrex Nine-O per acre. Dual is also cleared in a combination with atrazine plus Princep.

Bicep 6L is a 5:4 premix of metolachlor (Dual) plus atrazine used at 1½ to 3 quarts per acre. **Lariat 4L** and **Bullet 4L** are 5:3 premixes of alachlor (Lasso) plus atrazine used at 2½ to 4½ quarts per acre.

Dual or Lasso plus Bladex may be applied before planting and incorporated, or either combination may be applied preemergence at planting. The rate is 2 to 4 quarts of Lasso 4E or 1¼ to 2½ pints of Dual 8E plus 1 to 3¾ pounds of Bladex 80W or 1 to 3 quarts of Bladex 4L per acre. Adjust the rate carefully according to soil texture and organic-matter content.

Preemergence herbicides (corn)

Banvel (dicamba) may be applied immediately after planting, at the rate of one pint per acre on medium- to fine-textured soils having at least 2-percent organic matter. Do not apply preemergence to coarse-textured soils or any soils having less than 2-percent organic matter (4 percent when applied with Lasso). Banvel may be applied preemergence to early postemergence in tank-mix combinations with atrazine, Bladex, Lasso, Dual, or Prowl. **Marksman** is a premix of dicamba (Banvel) with atrazine. Refer to the labels for rates, timing, and precautions when using these combinations.

Prowl (pendimethalin) may be used in corn only after planting: do not incorporate. Corn should be planted at least 1½ inches deep. Prowl can control annual grasses, pigweed, and lambsquarters. The Prowl rate is 1½ to 4 pints alone or 1½ to 3 pints in combination with atrazine or Bladex. Prowl may also be tank-mixed with Banvel and applied to medium or fine soils at a rate of 3 pints of Prowl and ¾ pint of Banvel. These tank-mixes may be applied after corn emergence but before the crop reaches the four-leaf stage and weeds reach the one-inch stage. Avoid postemergence application when corn is under stress from cool, wet weather. Do not apply postemergence in liquid fertilizer.

Postemergence herbicides (corn)

Lasso, Dual, Ramrod, or Prowl may be combined with atrazine for application after planting to very early postemergence. The same is true for Lasso or Dual combined with Banvel. To obtain satisfactory control, apply before grasses reach the two-leaf stage. Early postemergence applications should be made using water, not liquid fertilizer, as a carrier. For more information, see the section on "Postemergence herbicide principles."

Atrazine may be applied when grass weeds are no more than 1½ inches high. Many annual broadleaf seedlings are more susceptible than grass weeds and may be treated until they are 4 inches tall. For control of some broadleaf weeds, 1.2 pounds active ingredient of atrazine may be sufficient. In most cases, this rate should be increased to 2 pounds for control of annual grass weeds.

The addition of oil-surfactant mixes or surfactants has generally increased the effectiveness of postemergence atrazine. Crop oil concentrates, COC's (80-percent oil and 20-percent surfactant), are used at the rate of one quart per acre.

An atrazine-and-oil mix sometimes injures corn that has been under stress from prolonged cold, wet weather or other factors. Do not use more than 2½ pounds of atrazine 80W, 2 quarts of atrazine 4L, or 2.2 pounds AAtrex Nine-O per acre if you mix with oil or an oil concentrate. *Do not add 2,4-D to the atrazine-oil treatment, or severe injury may result.* Mix the atrazine with water first, and add the oil last. If atrazine is applied after June 10, do not plant any crop except corn or sorghum the next year.

Bladex (cyanazine) may be applied until the fifth leaf of corn is visible and before grass weeds exceed 1.5 inches in height. The rate is 1.5 to 2.5 pounds Bladex 80W or 1.1 to 2.2 pounds Bladex 90DF per acre. *Do not use Bladex 4L postemergence.* Either a tank-mix (Bladex and atrazine) or a premix (Extrazine II) may also be applied postemergence.

Do not apply Bladex alone or with atrazine (tank-mix or premix) postemergence either in cold, wet weather or to corn that is stressed. Injury to corn is more likely under these conditions. Under droughty conditions, certain agricultural surfactants or vegetable oils may be added to Bladex 80W and 90DF. Do not use these spray additives with Extrazine II. Do not use petroleum crop oils or apply Bladex or Extrazine II with liquid fertilizers. Do not apply Bladex or Extrazine II to corn grown for seed. *Bladex and Extrazine II are classified as restricted-use pesticides.*

Tandem (tridiphane) may be used with atrazine, Bladex, or both for postemergence control of both annual grass and broadleaf weeds in field corn. These combinations should be applied when annual grass weeds are in the one- to three-leaf stage and actively growing. The rates per acre are 1 to 1½ pints of Tandem plus 1½ to 4 pints of atrazine 4L (equivalent rates of 80W or 90DF) or 1 to 2½ pounds of Bladex 80W (equivalent rates of 90DF). *Do not use Bladex 4L in combination with Tandem.* Crop oil concentrate (2 pints per acre) should be used with the tank-mixes that do not contain Bladex. Special programs are labeled for control of larger grasses, woolly cupgrass, and wild proso millet. See the Tandem label for more information on these programs.

Banvel (dicamba) may be applied early postemergence when corn is in the spike to five-leaf stage or up to 8 inches tall. The rate is one pint of Banvel per acre on medium- and fine-textured soils or one-half pint on coarse-textured soils. Corn tolerance is better and the potential for drift is less with the early treatment. Banvel may be tank-mixed with Lasso, Dual, Bladex (not 4L), or atrazine and applied early postemergence. See the label for rates, timing, and specific precautions.

Banvel may also be applied at one-half pint per acre to corn more than 8 inches tall but less than 36 inches tall. Weeds should be less than 12 inches tall for best control. Use drop nozzles on corn over 8 inches tall (Banvel alone or with 2,4-D) to improve corn tolerance and improve spray coverage to the weeds. Do not apply Banvel within 15 days of tassel emergence.

To minimize risk of drift injury, do not apply Banvel to corn over 24 inches tall, if nearby soybeans are over 10 inches tall or have begun to bloom. Observe all label precautions concerning spray pressure, spray volume, nozzle selection, wind speed, and temperature in order to minimize risk of vapor or spray drift to nearby susceptible crop or ornamental plants.

Marksman is a 1:2 premix of dicamba (Banvel) and atrazine that may be applied when corn is in the spike to five-leaf stage. The rate is 3½ pints per acre on medium- or fine-textured soils that contain over 2-percent organic matter. Marksman may be tank-mixed with Bladex (not 4L), Dual, Lasso, or Prowl for very early postemergence application. See the label for rates, timing, and precautions. Drift precautions are the same as with Banvel.

If weeds are drought-stressed, the addition of an approved agricultural surfactant to Banvel or Marksman will improve coverage and control. The Banvel (not Marksman) label calls for directed spray application if applied with a surfactant or with 2,4-D. Do not use adjuvants containing penetrants such as petroleum or crop oils because corn injury can be severe.

2,4-D is effective in controlling many broadleaf weeds in corn. If corn is more than 8 inches tall, use drop nozzles to decrease the possibility of injury to the corn. If you direct the nozzles toward the row, adjust the spray concentration so that excessive amounts are not applied to the corn.

The suggested broadcast rate is one-third to one-half pint of ester or one pint of amine for formulations with 3.8 pounds of 2,4-D acid-equivalent per gallon. Use equivalent rates with other formulation concentrations. Use proportionately less 2,4-D when using directed nozzles.

Do not apply 2,4-D to corn from the tasseling stage to the dough stage. After the hard dough to dent stage, you may apply 1 to 2 pints of certain 2,4-D formulations by air or high-clearance equipment to control some broadleaf weeds that may interfere with harvest or to suppress certain perennial weeds. Do not forage or feed fodder for 7 days after treatment.

The ester forms of 2,4-D can vaporize and injure nearby susceptible plants. This vapor movement is more likely with high-volatile esters than with low-volatile esters. Spray particles of either the ester or the amine form can drift and cause injury.

Corn is often brittle for 7 to 10 days after application of 2,4-D and thus is susceptible to stalk breakage from high winds or cultivation. Other symptoms of 2,4-D injury are stalk bending or lodging, abnormal brace roots, and failure of leaves to unroll. Injury problems are unlikely once corn has reached the brown silk stage.

High temperature and high humidity can increase the potential for 2,4-D injury, especially if corn is growing rapidly. If it is necessary to spray under these conditions, it may be wise to reduce the rate by about 25 percent. Corn hybrids differ in their sensitivity, and the probability of injury increases when corn is under stress.

Buctril (bromoxynil) may be used to control broadleaf weeds in field and silage corn. It is important to treat when the weeds are small. For ground applications, use at least 10 gallons of water per acre, a spray pressure of 30 psi, and flat-fan nozzles.

Buctril does not volatilize and cause the drift injury associated with 2,4-D or Banvel. Under some conditions, Buctril may cause temporary burning of corn leaves. Do not add a surfactant or crop oil to Buctril used alone or in combination.

Buctril 2E rates are 1 to 1½ pints per acre while weeds are in the three- to eight-leaf stage. Corn should be at the three-leaf stage for the low rate and 4-leaf stage for the higher rate. Buctril can be applied to corn up to tassel emergence. Use the higher rate on larger corn and weeds. Although most annual broadleaf weeds are controlled, larger pigweed and velvetleaf may require the higher rate or a combination with atrazine.

Buctril may be tank-mixed with atrazine 4L at one-half to one quart per acre (or equivalent rates of 80W or 90DF). **Buctril/atrazine 3L** is a 1:2 premix used at 1½ to 3 pints per acre. The rate varies with the size of the corn and weeds. Do not apply before the three-leaf stage of corn or after the corn is 30 inches tall. *Buctril is a restricted-use pesticide.*

Laddok (bentazon plus atrazine) is registered for postemergence broadleaf weed control in corn. Laddok does not control grasses. Corn has good tolerance to Laddok.

Laddok is effective mainly through contact action; therefore, weeds must be thoroughly covered with spray. Laddok rates range from 2.5 to 3.5 pints per acre. Always add UAN (urea ammonium nitrate) solution or an oil concentrate to Laddok. For ground application, use one gallon per acre of UAN solution; and, for aerial application, use one-half gallon per acre. If UAN solution is not used, a nonphytotoxic oil concentrate should be added to the spray tank.

Use the oil concentrate if Canada thistle or yellow nutsedge is to be treated. For ground application, use no more than 2 pints per acre of the oil concentrate; and, for aerial application, use no more than 1 pint per acre.

Laddok provides better control of velvetleaf, annual morningglory, lambsquarters, and pigweed than does Basagran alone and will create less risk of carryover than do higher rates of atrazine alone.

Roundup (glyphosate) may be applied as a spot treatment in corn prior to silking. For applications made on a spray-to-wet basis, use a 1- to 2-percent solution of Roundup in water. Avoid contact of spray with the corn.

Postemergence soil-applied herbicides (corn)

Some soil-applied herbicides may be applied to the soil as a postemergence treatment in corn. It may be necessary to use drop nozzles to avoid interference from corn leaves and ensure uniform application to the soil.

Prowl (pendimethalin) or Treflan (trifluralin) may be applied to the soil and incorporated after field corn is 4 inches tall (for Prowl) or 8 inches tall (for Treflan) and up to the time of the last cultivation. The field should be cultivated to control existing weeds and cover the roots at the base of the corn before application. The herbicide should then be thoroughly and uniformly incorporated into the top inch of the soil with a sweep-type or rolling cultivator. Prowl may not require incorporation if irrigation is used or rainfall occurs soon after application. Prowl or Treflan may be combined with atrazine.

These Prowl or Treflan treatments may help control late-emerging grasses such as shattercane, wild proso millet, fall panicum, or woolly cupgrass.

Dual (metolachlor) or Bicep (metolachlor plus atrazine) may be used for postemergence "lay-by" treatments in corn. For Dual, as much as 3 pounds of active ingredient per acre may be used in a single application, up to a total of 6 pounds of active ingredient in one year. With Bicep, as much as 3 quarts of 6L may be used per acre.

Directed postemergence herbicides (corn)

Directed sprays are sometimes needed for emergency situations, especially when grass weeds become too tall to be controlled by cultivation. Weeds, however, are often too large for directed sprays to be effective. Directed sprays cannot be used on small corn because a height difference between corn and weeds is needed to keep the spray off the corn. The spray may kill corn leaves that come into contact with it, and injury can affect yields. *Consider these to be emergency treatments.*

Lorox or Linex (linuron) may be applied as a directed spray after corn is at least 15 inches tall (freestanding) but before weeds are 8 inches tall, preferably when weeds are no more than 5 inches tall. Linuron controls broadleaf and grass weeds.

The broadcast rate is 1¼ to 3 pounds of linuron 50W or 50DF or 1¼ to 3 pints of 4L per acre, depending on weed size and soil type. Add Surfactant WK at the rate of 1 pint per 25 gallons of spray mixture. Cover the weeds with the spray, but keep it off the corn as much as possible.

Evik 80W (ametryn) is registered for directed use when corn is more than 12 inches tall and weeds are less than 6 inches tall. Evik should not be applied within 3 weeks of tasseling. The rate is 2 to 2½ pounds Evik 80W per acre (broadcast) plus 2 quarts of surfactant per 100 gallons of spray mixture. Extreme care is necessary to keep the spray from contacting the leaves.

Gramoxone Extra (paraquat) may be applied as a directed spray after corn is 10 inches tall but before weeds are 4 inches tall. The rate is 12.8 fluid ounces of Gramoxone Extra per acre in 20 to 40 gallons of water. Add 1 quart of nonionic surfactant per 100 gallons of spray volume. Control of broadleaf weeds such as smartweed can be improved by adding 1 to 2 pints per acre of atrazine 4L (or equivalent rates of 80W), Bladex, or Princep. Observe all label precautions. *Gramoxone is a restricted-use pesticide.*

Herbicides for sorghum

Many herbicides used to control weeds in corn may also be used in sorghum.

Bronco (alachlor plus glyphosate) may be used alone or with atrazine where grain sorghum is to be planted directly into a cover crop or in the residue of the previous crop. Bronco can control emerged annual weeds and may control or suppress many emerged perennial weeds, as well as give preemergence grass control. Grain sorghum seed must be treated with Screen (flurazole), as it is when Lasso is used. *Bronco is a restricted-use pesticide.*

Gramoxone Extra or Super (paraquat) can control existing annual weeds where grain sorghum is to be planted into the residue of the previous crop. *Gramoxone is a restricted-use pesticide.*

Atrazine may be used for weed control in sorghum (grain and forage types) or sorghum-sudan hybrids, with application made preemergence or postemergence. A preplant surface application may be made using a single application within 30 days of planting or a two-thirds plus one-third split application within 45 days of planting. Plant the seed at least one inch deep. Do not use preplant or preemergence on soils with less than 1-percent organic matter. Atrazine can cause injury to sorghum if rainfall occurs before or shortly after sorghum emergence.

Injury may also occur when sorghum is under stress from unusual soil or weather conditions or when rates are too high. The rate of application for preplant and preemergence is 2 to 3 pounds of atrazine 80W per acre. The postemergence rate is 4 to 6 pints 4L per acre without crop oil or 2.4 pints 4L (broadleaf control only) with crop oil or crop oil concentrate. Use equivalent rates of atrazine 80W or AAtrex 90DF formulations. Rotational crop recommendations and weed control are the same as for atrazine used in corn. Failure to control fall panicum has been a major problem.

Ramrod (propachlor) may be used alone or in combination with atrazine or Bladex for sorghum. Ramrod can improve grass control; but rates must not be maintained, especially on soils that are relatively low in organic matter. Do not graze or feed forage to dairy animals.

Lasso (alachlor) alone or plus atrazine may be preplant incorporated or used preemergence for grain sorghum if seed is treated with Screen (flurazole). This use also applies to Lariat and to Bronco. *Products containing alachlor are restricted-use pesticides.*

Dual (metolachlor) or Bicep (metolachlor plus atrazine) may be used for sorghum if seed has been treated with Concep II. These herbicides will control grasses better than will atrazine applied alone. An early preplant treatment of Dual or Bicep may be used in a similar manner as for corn, but it is still necessary to use seed that has been treated with Concep II.

Laddok (bentazon plus atrazine) is registered for postemergence broadleaf weed control in sorghum in a similar manner as for corn. (See the section entitled "Herbicides for corn.") Adding 28-percent UAN solution or crop oil concentrate is considered relatively safe. Do not apply Laddok to grain sorghum that is heading or blooming. Laddok use rates range from 2.5 to 3.5 pints per acre.

2,4-D may be applied postemergence for broadleaf control in sorghum that is from 4 to 24 inches tall. Use drop pipes on nozzles if sorghum is more than 8 inches tall. Rates are similar to those for corn. (See the section entitled "Herbicides for corn.")

Banvel (dicamba) may be applied postemergence to sorghum up to 21 days after emergence but before sorghum is 15 inches tall. The rate is one-half pint per acre. Do not graze or feed treated forage or silage before the mature grain stage. Sorghum can be injured by Banvel, and seed development can be affected.

Buctril (bromoxynil) can control small broadleaf weeds in grain sorghum from the three-leaf up to the boot stage. A tank-mix with atrazine or the Buctril/atrazine mixture may be used. See the label for rates, timing, and weed sizes. *Buctril is a restricted-use pesticide.*

Prowl (pendimethalin) may be applied to grain sorghum from the 4-inch growth stage until the last cultivation, primarily for control of late-season annual grass weeds. For more information, see the subsection on postemergence soil-applied herbicides under "Herbicides for corn."

Roundup (glyphosate) may be applied as a spot treatment in sorghum (milo) prior to heading. For applications on a spray-to-wet basis, use a 1- to 2-percent solution of Roundup in water. With motorized spot treatments from which less complete coverage of weeds may result, use a 5-percent solution. Avoid spray contact with the sorghum.

Herbicides for soybeans

Consider the kinds of weeds expected when you plan a herbicide program for soybeans. The herbicide selectivity table lists herbicides and their relative weed control ratings for various weeds. (See Tables 7 to 10 for soybean herbicides.)

Although soybeans may be injured by some herbicides, they usually outgrow early injury with little or no effect on yield if stands have not been significantly reduced. Significant yield decreases can result when injury occurs during the bloom to pod-fill stages. Excessively shallow planting can increase the risk of injury from some herbicides. Accurate rate selection for soil type is essential for herbicides containing metribuzin (Canopy, Lexone, Preview, Salute, Sencor, or Turbo) or linuron (Linex, Lorox, or Lorox Plus). Do not apply these herbicides after soybeans begin to emerge, or severe injury can result. Always follow label instructions. See Table 7 for some preplant and preemergence tank-mix combinations.

Preplant not incorporated (soybeans)

Early preplant application of herbicides can be used in many minimum tillage programs to minimize existing vegetation problems at planting and reduce the need for a knockdown herbicide. Preemergence herbicides for early application before planting soybeans are Dual for grass control and Canopy, Lexone, Lorox Plus, Preview, Pursuit, Sencor, and Scepter for broadleaf control. All except Dual have both soil and foliar activity, so they may control some small annual weeds prior to planting soybeans, especially if a nonionic surfactant or crop oil concentrate is added to the spray mix. However, if weeds are over 1 to 2 inches tall, add either Gramoxone, Roundup, or Bronco to the spray mix to control existing vegetation. (See the section "Conservation tillage and weed control.")

Dual can be applied up to 30 days prior to planting or as a split application within 45 days of planting soybeans. The split application rate is a full rate with two-thirds applied preplant and one-third at planting.

Canopy, Lorox Plus, and Preview can be applied early preplant up to 30 days before planting soybeans. However, if applied with Dual, this is reduced to 14 days and with Lasso, to 7 days.

Sencor plus Lasso or Dual may be applied up to 30 days before planting soybeans if applied as a split preplant and at planting application. **Turbo** is a premix of Sencor and Dual.

Pursuit, Pursuit Plus, Passport, Scepter, and Squadron can be applied up to 45 days before planting soybeans. However, if sufficient rain does not occur before planting, then mechanical incorporation is required.

Roundup and Poast can also be used before planting soybeans. Roundup may be used preplant in soybeans

Table 7. Herbicide Tank-Mixes for PPI or PRE Use in Soybeans

Herbicide	Sencor or Lexone	Canopy or Preview	Scepter*	Pursuit	Command	Amiben
PPI						
Cannon	1	1	1	–	1	–
Command	1	1	1	–	–	–
Commence	1	1	1	–	–	–
Freedom	1	1	1	–	1	–
Salute	–	–	1	–	1	–
Sonalan	1	1	–	–	1	1
Trifluralin	1	1	1	1	1	1
PPI or Pre						
Dual	1,2	1,2	1,2	1,2	1	1,2
Lasso	1,2	1,2	1,2	1,2	1	1,2
Prowl	1,2	1,2	1,2	1,2	1	1,2
Turbo	–	–	1,2	–	1	–
	Sencor + Scepter*	**Sencor + Command**	**Command + Scepter***	**Lorox or Linex**	**Lorox+**	**Treflan**
PPI Only						
Command	–	–	–	–	–	1
Sonalan	–	1	–	–	1	–
Treflan	1	1	1	–	1	–
PPI or Pre						
Dual	1,2	1	1	2	1,2	1
Lasso	1,2	1	1	2	1,2	1
Prowl	1,2	1	1	2	2	–

* Only in Scepter label's "southern use area."
Note: 1 = preplant incorporated, 2 = preemergence, and – = not registered.

Table 8. Soybean Herbicides and Crop Rotation Restrictions

Herbicide	pH	FC	SC	GS	WT	OT	RY	ALF	CLO
				(Months after application prior to)					
Canopy	≤6.8	10	18	12	4	18	18	10	12
Classic	≤7.0	9	**	9	3	3	3	9	9
Command	–	9	9-12	9	12	16	16	16	16
Commence	–	9	9	9	12	16	16	16	16
Lorox Plus	≤6.8	10	18	10	4	4	4	**	12
Preview	≤6.8	10	18	12	4	4	4	10	12
Reflex	–	10	10	18	4	4	4	18	18
Pursuit##	–	9.5	18	18	4	18	18	18	18
Scepter (northern area) (1/3 pint/A post)	–	11*	18	11	4	4	18	18	18
Scepter (northern area)# (2/3 pint/A)	–	18	18	11	16	16	16	18	18
Scepter (southern area)#	–	11*	18	11	4*	11	18	18	18

Applies also to Squadron, Tri-Scept, and Ala-Scept.
Applies also to Pursuit Plus and Passport.
* 15 inch rainfall restriction.
** Bioassay after 9 months.
Note: pH = soil pH restrictions, FC = field corn, SC = seed corn, GS = grain sorghum, WT = wheat, OT = oats, RY = rye, ALF = alfalfa, and CLO = clover.

to control small annual weeds. The rate is 0.75 to 1 pint per acre in 5 to 20 gallons of water with the addition of a surfactant. Poast can be used at 0.5 pint per acre before planting soybeans to control small annual grasses. Always add crop oil concentrate or Dash with Poast.

2,4-D application prior to planting soybeans is controversial. Poast labeling allows preplant application with 2,4-D LVE, but the label states, "Do not plant soybeans for 3 months after treatment or until the 2,4-D LVE has *disappeared* from the soil." Canopy, Lorox Plus, Preview, Sencor, and Turbo labels allow tank-mixing with 2,4-D LVE when applied 30 days before planting soybeans. Yet, these labels allow twice the rate of 2,4-D as on the Poast label. A residue tolerance for 2,4-D in soybeans has not been established. There is *no 2,4-D label allowing use in the spring prior to planting soybeans.* The legality of these treatments as used is questionable.

Soil-applied "grass" herbicides (soybeans)

Treflan, Sonalan, and Command are soil-applied herbicides for grass control which require mechanical incorporation, while Prowl, Lasso, and Dual can be used preemergence or preplant incorporated. Incorporation improves herbicide performance if rainfall is limited. For more information, see the section entitled "Herbicide incorporation."

Treflan, Sonalan, and Prowl are dinitroaniline (DNA) herbicides which control annual grasses, pigweed, and lambsquarters. Control of additional broadleaf weeds requires combinations (see Tables 6 and 7) or sequential treatments with other herbicides.

Soybeans are sometimes injured by DNA herbicides. Symptoms are stunting, swollen hypocotyls, and short, swollen lateral roots. Usually, such injuries are not serious. If incorporation is too shallow or Prowl is used preemergence, soybean stems may be calloused and brittle, leading to lodging or stem breakage.

DNA herbicides can sometimes carry over and injure rotational crops of corn or sorghum. Symptoms appear as reduced stands and stunted, purple plants with poor root systems. Under good growing conditions, corn typically recovers from this early season injury. Accurate, uniform incorporation is needed to minimize potential carryover.

Treflan, Trilin, or Trifluralin (trifluralin) may be applied alone anytime in the spring prior to planting. However, tank-mixes may specify application closer to soybean planting. Incorporate trifluralin within 24 hours after application or within 8 hours if the soil is warm and moist. The rate per acre is 1 to 2 pints of 4E or equivalent rates of Pro-5 or 10G. A slightly higher rate and deeper incorporation may be specified for shattercane control.

Sonalan 3E (ethalfluralin) may be applied at 1.5 to 3 pints per acre within 3 weeks before planting and should be incorporated within 2 days after application. There is a greater risk of soybean injury from Sonalan than with trifluralin, so incorporation must be uniform. Sonalan is less likely than trifluralin to carry over and injure corn the following year.

Prowl 4E (pendimethalin) may be applied at 1 to 3 pints per acre up to 60 days (less for some tank-mixes) before planting soybeans. Preplant treatments should be incorporated within 7 days unless adequate rainfall occurs to incorporate the herbicide. *South of Interstate 80,* Prowl may also be applied preemergence up to 2 days after planting.

Command 4E (clomazone) is used at 1.5 to 2 pints per acre to control annual grasses, velvetleaf, and several other broadleaved weeds. Use the higher rate if Command is applied more than 30 days prior to planting. Command is also used at lower rates in some tank-mixes for velvetleaf control (see Table 7). **Commence 5.25L** is a premix of Command and Treflan used at 1.75 to 2.67 pints per acre.

Incorporate Command or Commence immediately if the soil is moist or within 8 hours after application

Table 9. Soybean Postemergence Herbicides: Broadleaf Weed Control

Herbicide	AMG	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	SBN
Contact postemergence broadleaf													
Basagran	4	9+	9	6	3	4	7	8	9	8	8	8+	0
Blazer/Tackle	8	7	9	5	8	10	9	8	9	7	2	6	2
Galaxy	6	9	9	6	6	9	8	8	9	8	7	8+	1
Storm	7	8+	9	5	7	9	9	8	9	8	6	8	1+
Cobra	7	8+	9	4	8	10	9	8	6	8	6	7	3
Reflex	7	7	9	5	7	9	8	6	7	7	2	6	1
Systemic postemergence broadleaf													
Classic	7	9+	8+	2	3	9	8	7	8	9	4	7	1
Pinnacle	4	6	4	8+	4	8+	4	4	8	6	4	8+	1+
Classic and Pinnacle	6	9+	8+	8+	4	9	6	5	8	8	4	8+	1+
Pursuit	7	8+	7	4	8	9	6	8	8	9	6	8+	1
Scepter	2	9+	4	3	5	10	6	3	6	7	2	3	1
Rescue	7	8	4	4	3	4	3	7	5	6	2	3	4

Note: AMG = annual morningglory, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and SBN = soybean response.

Table 10. Postemergence Herbicide Tank-Mixes

	Basagran	Blazer	Tackle	Reflex	Cobra	Classic
Registered for broadleaf weed control in soybeans						
Basagran	–	X	X	X	X	X
Classic	X	X	X	X	X	–
Scepter	X	X	X	X	X	–
Pinnacle	–	–	–	–	–	X
Rescue	–	X	X	–	–	–
2,4-DB	X	X	X	X	X	X
*Registered for grass + broadleaf weed control in soybeans**						
Assure	X	–	–	–	–	X
Fusilade	X	X	X	X	–	–
Option	X	X	X	–	–	–
Poast Plus	X	X	X	–	–	–

* Check labels for special instructions. Sequential application may be preferable (see below).
Note: X = registered and – = not registered.

if the soil is dry. You must minimize drift (spray or vapor) to sensitive plants. Avoid applying within 100 feet of trees, ornamentals, vegetables, alfalfa, or small grains or within 1,000 feet of subdivisions or towns, nurseries, greenhouses, and commercial fruit or vegetable (except sweet corn) production areas.

Minimum recropping intervals are 9 months for field corn or sorghum and 12 months for wheat. See Table 8 or the label for more information. Carryover injury will appear as whitened or bleached plants after emergence. Corn has usually outgrown modest injury with little effect on yield. However, injury may be severe if application or incorporation is not uniform. Corn hybrids vary in tolerance to clomazone.

Dual (metolachlor) and Lasso (alachlor) can be applied preplant or preemergence to control annual grasses and pigweed. Use the higher rates to improve black nightshade control and incorporate to improve yellow nutsedge control. They can be combined with other herbicides to improve broadleaf control (see Tables 6 and 7). Dual can be applied up to 30 days prior to planting soybeans. The rate per acre is 1.5 to 3 pints of 8E or 6 to 12 pounds of 25G. Lasso can be applied up to 7 days prior to planting soybeans. The rate per acre is 2 to 4 quarts of 4E or 4L (MicroTech), or 16 to 26 pounds of 15G. Arena, Judge, Stall, Saddle, and Confidence are private brands of alachlor in the market. *All herbicides containing alachlor are restricted-use pesticides.*

Cannon and Freedom are premixes of alachlor (Lasso) and trifluralin (Treflan). They control the same weeds as Lasso (see Tables 5 and 6), but require incorporation within 24 hours because of the trifluralin. *Cannon 3E* is for darker, heavier soils at a rate of 3 to 5 quarts per acre. *Freedom 3E* is for lighter soils such as occur in southern Illinois, and the rate is 2.75 to 4.5 quarts per acre. *Cannon and Freedom are restricted-use pesticides.*

Soil-applied "broadleaf" herbicides (soybeans)

Amiben, Canopy, Command, Lexone, Lorox, Lorox Plus, Preview, Pursuit, Scepter, and Sencor are soil-applied herbicides used for broadleaf weed control in soybeans. Lorox is not to be incorporated and Command must be incorporated (Command is discussed in the "grass" herbicide section). The others can be used preplant incorporated or preemergence after planting soybeans.

Timely rainfall or incorporation is needed for uniform herbicide placement in the soil. Incorporation may improve control of deep-germinating (large-seeded) weeds especially when soil moisture is limited. Accurate and uniform application and incorporation are essential to minimize potential soybean injury. Except for Amiben and Command, these herbicides are photosynthetic inhibitors (PSI), meristematic inhibitors (MSI), or premixes of MSI (chlorimuron) and PSI's (metribuzin or linuron).

Photosynthetic (PSI) inhibitors

Metribuzin (Sencor or Lexone) and linuron (Lorox or Linex) are photosynthetic inhibitors (PSI). Canopy, Preview, Salute, and Canopy are premixes which contain metribuzin while Lorox plus is a premix which contains linuron. These PSI herbicides can cause soybean injury from foliar or soil uptake, *so do not apply them after soybeans emerge.*

PSI herbicide injury symptoms are yellowing (chlorosis) and dying of lower soybean leaves usually appearing about the first trifoliolate stage. Atrazine and simazine carryover can intensify these symptoms. Soybeans usually recover from moderate PSI injury that occurs early. Metribuzin injury may be greater on soils with pH over 7.5. Soybean varieties differ in their sensitivity to metribuzin.

Sencor or Lexone (metribuzin) may be applied anytime within 14 days before planting soybeans. The Sencor or Lexone rate per acre used in tank-mixes is 1/2 to 1 pint of 4L or 1/3 to 2/3 pound of 75DF. Accurately adjust the rates according to soil texture and organic matter content. *Do not apply to sandy soil that is low in organic matter.* Reduced rates minimize soybean injury but lessen weed control. Split preplant and preemergence applications allow higher rates to improve weed control. Sencor or Lexone can control several annual broadleaves (see Table 6) and can be tank-mixed with many herbicides to improve control of other species (see Table 7).

Turbo 8E, a premix of metribuzin (Sencor) plus metolachlor (Dual), can be applied preplant incorporated or preemergence. The rate per acre is 1.5 to 3 pints.

Salute 4E, a premix of metribuzin (Sencor) plus trifluralin (Treflan), is applied preplant at 1.5 to 3 pints per acre and must be incorporated within 24 hours.

Preview 75DF and Canopy 75DF are premixes of metribuzin (Lexone) and chlorimuron (Classic) while **Lorox Plus** 60DF is a premix of linuron (Lorox, see below) and chlorimuron (Classic). These premixes may be applied preemergence or preplant incorporated. They control cocklebur, velvetleaf, and wild sunflower better than metribuzin or linuron alone (see Table 6). Combinations with the grass herbicides can improve grass control (see Tables 5 and 7). Preview and Canopy contain significant amounts of chlorimuron (Classic) as well as metribuzin, so they can provide some burndown of small weeds as well as residual control for minimum tillage systems.

Broadcast rates per acre are 6 to 10 ounces of Preview 75DF, 4 to 7 ounces of Canopy 75DF, and 12 to 28 ounces of Lorox Plus 60DF. *Do not apply Preview, Canopy, or Lorox Plus to soils with pH greater than 6.8.* High soil pH may occur in localized areas in a field. Correct rate selection for the soil plus uniform, accurate application and incorporation are essential to minimize soybean injury and potential follow crop injury. See PSI injury symptoms (above) and MSI injury symptoms (below).

Minimum recropping intervals for Preview, Canopy, and Lorox Plus are 4 months to wheat and 10 months to field corn. If Classic, Pursuit, or Scepter is applied the same year as Preview, Canopy, or Lorox Plus, the risk of carryover can increase so labels should be checked carefully for rotational guidelines.

Lorox or Linex (linuron) is used after planting soybeans and before the crop emerges. Lorox is best suited to the silt loam soils of southern Illinois that contain 1- to 3-percent organic matter where the rate per acre is 1 to 1⅔ pounds (50DF) or pints (4L) per acre. *Do not apply to very sandy soils or soils containing less than 0.5 percent organic matter.*

Meristematic inhibitors (MSI)

Imazethapyr (Pursuit), imazaquin (Scepter), and chlorimuron (in Canopy, Preview, and Lorox Plus, see above) are meristematic inhibitors (MSI).

MSI herbicide injury symptoms include temporary yellowing of upper leaves (golden tops) and shortened internodes of soybeans. Although plants may be stunted, yield is generally not affected. These MSI herbicides may carry over and injure certain sensitive follow crops. Symptoms on corn or grain sorghum are stunted growth, inhibited roots, and interveinal chlorosis or purpling of leaves. Symptoms on small grains are stunted top growth and excess tillering.

Pursuit 2E (imazethapyr) is used at 4 fluid ounces per acre (32 acres per gallon) to control broadleaved weeds (see Table 6). Velvetleaf and jimsonweed control are more consistent with incorporation. Grass control is improved by tank-mixing Pursuit with a grass herbicide (see Table 7). **Pursuit Plus and Passport** are both premixes of Pursuit and Prowl or trifluralin, respectively. Both are used at 2.5 pints per acre, which is equivalent to 0.25 pint of Pursuit and 1.75 pint of Prowl or 1.5 pints of trifluralin, respectively.

Pursuit and Pursuit Plus can be applied up to 45 days prior to planting soybeans. If sufficient rain does not occur before planting, then mechanically incorporate. *South of Interstate 80,* Pursuit Plus can be surface-applied up to 2 days after soybean planting. Minimum recropping intervals for Pursuit, Pursuit Plus, and Passport are 4 months for wheat, 9.5 months for field corn, and 18 months for grain sorghum. Pursuit has less potential than Scepter to injure corn the next season on high organic matter soils, and it provides better control of velvetleaf. Thus, Pursuit is more adapted than Scepter to most soils of central and northern Illinois.

Scepter (imazaquin) is used at ⅔ pint 1.5E or 2.8 ounces of 70DG per acre and is applied within 45 days (less with many tank-mixes) before planting or immediately after planting. Scepter controls many broadleaf weeds such as pigweed and cocklebur (see Table 6) with adequate soil moisture, but it is somewhat weak on velvetleaf. Incorporation can improve weed control under low-rainfall conditions, and may improve control of velvetleaf and giant ragweed. Grass control is improved by mixing with "grass" herbicides (see Table 7).

Squadron, Tri-Scept, and Ala-Scept are premixes of imazaquin (Scepter) plus pendimethalin (Prowl), trifluralin, or alachlor (Lasso), respectively. The rate per acre is 3 pints of Squadron, 2.33 pints of Tri-Scept, or 5.33 pints of Ala-Scept. This is the equivalent of ⅔ pint of Scepter plus 1.5 pint of Prowl, 1.5 pint of trifluralin, or 2 quarts of Lasso per acre, respectively. Incorporate Squadron within 7 days unless sufficient rain occurs. Tri-Scept must be incorporated within 24 hours. Ala-Scept can be used preemergence or preplant incorporated.

A line across Peoria, extending west along Illinois Route 116 and east along U.S. Route 24, presently determines Scepter, Squadron, Tri-Scept, or Ala-Scept rotational crop restrictions (see Table 8).

There have been significant problems with carryover of Scepter and related premixes and tank-mixes in Illinois. Soil and climatic conditions plus lack of uniformity in application and incorporation are associated with the carryover problem. Carryover potential is greater on soils with high organic matter and low pH. *Research and field results indicate that in Illinois, Scepter, Squadron, and Tri-Scept are best adapted to the soils and weeds south of Interstate 70.* Reduced rates, which can reduce potential carryover, are allowed for postemergence use of Scepter and in tank-mixes with several other products. However, problems have arisen in determining corporate responsibility for product liability when Scepter has been used at reduced rates in tank-mixes.

Other "broadleaf" herbicides

Amiben (chloramben) can be used preemergence or preplant incorporated. Amiben is often applied as a band treatment after planting to control broadleaved weeds following a preplant application of a herbicide to control annual grasses. If rain does not occur within 3 to 5 days after preemergence application of Amiben, a rotary hoe should be used over the field. The broadcast rate of Amiben alone is 20 to 30 pounds of 10G, 4 to 6 quarts of 2S, or 2.4 to 3.6 pounds of 75DS per acre. Use the higher rate for control of black nightshade, common ragweed, velvetleaf, and annual grasses. Amiben generally performs best on the soils of moderate to high organic matter.

Command (clomazone) is often used as a broadleaf herbicide in tank-mixes, but it also controls annual grasses. See discussion under soil-applied "grass" herbicides.

Postemergence herbicides (soybeans)

Postemergence (foliar) herbicides are more effective when used in a planned program so that application is timely and not just an emergency or rescue treatment. Foliar treatments allow the user to identify the problem weed species and choose the most effective herbicide. Climatic conditions greatly affect foliar herbicides as penetration and action are usually greater with warm temperatures and high relative humidity. Rainfall soon after application can cause poor weed control. Weeds growing under droughty conditions are more difficult to control.

Rates and timing for foliar treatments are based on weed size. Early application when weeds are young and tender may allow the use of lower herbicide rates. Treatment of oversized weeds may only suppress growth temporarily and regrowth may occur. A cultivation 7 to 14 days after application but before regrowth can often improve weed control. However, cultivation during or within 7 days of a foliar application may cause erratic weed control.

Crop oil concentrates (COC) or nonionic surfactants (NIS) are usually added to the spray mixture to improve effectiveness of postemergence soybean herbicides. Dash is a special surfactant for use with Poast. Fertilizer adjuvants such as 28-0-0 (UAN) or 10-34-0 may be specified on the label to increase control of certain weed species, such as velvetleaf. *Do not use brass or aluminum nozzles with fertilizer adjuvants. All fertiilzer adjuvants should be rinsed from the tank before final cleanup with chlorine bleach.*

Postemergence herbicides for soybeans are either contact or translocated in action. Contact herbicides affect only the leaf tissue covered by the spray, so thorough spray coverage is critical. Contact herbicides should be applied to small weeds. Injury symptoms are usually noticeable within a day. Translocated herbicides do not require complete spray coverage as they move to the growing points (meristems) after foliar penetration. Their action is slow and symptoms may not appear for about a week.

Contact broadleaf herbicides

Basagran, Blazer, Tackle, Reflex, Cobra, Galaxy, and Storm are contact broadleaf herbicides. See Table 9 for weeds controlled. Spray volumes for ground application are 20 to 30 gallons per acre and spray pressure should be 40 to 60 psi. Hollow cone or flat-fan nozzles provide much better coverage than flood nozzles.

Low temperatures and humidity will reduce contact activity. Soybean leaves may show contact burn under conditions of high temperature and humidity. This leaf burn is intensified by crop oil concentrate or Dash. Soybeans usually recover within 2 to 3 weeks after application. A rain-free period of several hours is required for most effective control with most contact herbicides.

Smaller weeds that are actively growing may allow the use of reduced herbicide rates. Contact herbicides have little soil residual activity, so don't apply too early. Apply 2 to 3 weeks after soybean emergence or when soybeans are in the 1- to 2- trifoliolate stage. Larger weeds not only require increased rates, but the weeds may recover and regrow. Contact herbicides should not be applied after soybeans begin to bloom. Preharvest intervals are generally 50 to 90 days.

Basagran (bentazon) is used at 1 to 2 pints per acre. See the label for specifics on weed sizes and rates. Most weeds should be small (1 to 3 inches) and actively growing. Basagran controls cocklebur, smartweed, jimsonweed, and velvetleaf. Velvetleaf control is improved if 28-0-0 (UAN) is added to the spray mixture. Crop oil concentrate is preferred if the major weed species is common ragweed or lambsquarters. Split applications can improve control of lambsquarters, giant ragweed, wild sunflower, and yellow nutsedge. The addition of 2,4-DB can improve annual morningglory control. Do not spray if rain is expected within 8 hours.

Blazer or Tackle (acifluorfen) is used at 1 to 3 pints per acre when broadleaf weeds are 2 to 4 inches tall and actively growing. See the label for specifics on adjuvants and weed sizes. Weeds controlled include pigweed, annual morningglory, jimsonweed, and black nightshade. Velvetleaf control is improved with the use of fertilizer adjuvants or the addition of Basagran. Adding 2,4-DB can improve cocklebur and morningglory control. Blazer and Tackle may cause soybean leaf burn, especially if applied with crop oil concentrate instead of surfactant or fertilizer adjuvants. However, the crop usually recovers within 2 to 3 weeks. Do not spray if rain is expected within 4 to 6 hours.

Basagran plus Blazer or Tackle improves control of pigweed and morningglory over Basagran alone and of velvetleaf and cocklebur over Blazer or Tackle alone. Rates vary depending upon weed species and size. Fertilizer adjuvants can improve velvetleaf control. **Storm 4S and Galaxy 3.67S** are premixes of Basagran and Blazer. Storm at 1.5 pint per acre is equivalent to 1 pint of Basagran plus 1 pint of Blazer. Galaxy at 2 pints per acre is equivalent to 1.5 pints of Basagran plus 0.67 pint of Blazer. See the labels for adjuvant specifics.

Cobra 2E (lactofen) is applied at 12.5 fluid ounces per acre with crop oil concentrate (COC) at 0.5 to 1 pint per acre. One gallon per acre of 28-0-0 (UAN) may be substituted for COC under favorable growing conditions. Weeds controlled include cocklebur, pigweed, jimsonweed, common ragweed, and velvetleaf. Cobra usually causes soybean leaf burn, but soybeans usually recover within 2 to 3 weeks. Cobra can be tank-mixed with Basagran, Classic, Scepter, or 2,4-DB. Apply Cobra only once during the season and no later than 90 days before harvest. Do not apply if rain is expected within 30 minutes.

Reflex 2LC (fomesafen) is used at 0.75 to 1 pint per acre, north of Interstate 70 and at 1.25 pint south of Interstate 70. Add either crop oil concentrate at 1 gallon or nonionic surfactant at 1 to 2 quarts per 100 gallons of spray. Reflex controls pigweed, black nightshade, jimsonweed, smartweed, and common ragweed up to the 4-leaf stage. Reflex can be tank-mixed with Basagran, Classic, or Scepter to broaden the spectrum of control. Do not spray if rain is expected within 4 hours of application. *Do not apply Reflex beyond 3 weeks after soybean emergence.* There is a potential for carryover, so be sure that applications are accurate and even. Recrop intervals are 4 months for small grains, 10 months for corn, and 18 months for other crops.

Translocated broadleaf herbicides

Classic, Pinnacle, Pursuit, and Scepter are translocated herbicides which primarily control broadleaf weeds in soybeans. See Table 9 for weeds controlled. All four have the same mode of action and some soil residual activity. Weeds should be actively growing (not moisture or temperature stressed). Do not make applications when weeds are in the cotyledon (very early seedling) stage. Annual weeds are best controlled when less than 3 to 5 inches tall (within 2 to 4 weeks after soybean emergence). A one-hour rain-free period is usually adequate for these herbicides.

These herbicides inhibit growth of new meristems so symptoms of weed injury may not be exhibited for 3 to 7 days. Injury symptoms are yellowing of leaves followed by death of the growing point. Death of leaf tissue in susceptible weeds is usually observed in 7 to 21 days. Less susceptible plants may be suppressed, remaining green or yellow but stunted for 2 to 3 weeks.

Soybeans may show temporary leaf yellowing (golden tops) and/or growth retardation (stunting), especially if the soybeans are under stress. Under favorable conditions, affected soybeans may recover with only a slight reduction in height and no loss of yield.

Total spray coverage is not critical for translocated herbicides. A minimum spray volume of 10 gallons per acre may be used for ground application using flat-fan nozzles at 20 to 40 psi or hollow cone nozzles at 40 to 60 psi. Nonionic surfactants (NIS) are usually specified at 1 to 2 pints per 100 gallons of spray. Crop oil concentrate (COC) may improve weed control, but may increase crop injury. Fertilizer additives (28-0-0 or 10-34-0) improve control of some weeds, and are specified for velvetleaf control on the Classic, Pinnacle, and Pursuit labels. Tank-mixing these herbicides with postemergence herbicides for grass may reduce grass control, so sequential applications are often specified.

Classic 25DF (chlorimuron) is used at 0.5 to 0.75 ounce per acre plus 1 quart of surfactant or 1 gallon of crop oil concentrate per 100 gallons. Fertilizer adjuvants improve velvetleaf control. Classic can control cocklebur, jimsonweed, wild sunflower, and yellow nutsedge. Pigweed control varies with rate and species. Check the label for weed sizes and rates. Split applications can improve control of burcucumber, giant ragweed, and annual morningglory. Do not apply Classic within 60 days of harvest. *Do not apply Classic if soil pH is over 7.0.* Recrop intervals are 3 months for small grains and 9 months for field corn, sorghum, alfalfa, or clover. If Classic is applied after Preview, Canopy, Lorox Plus, Pursuit, or Scepter, check the label for recrop intervals. Carryover injury to corn can occur, especially if soil pH is above 7.0. Corn appears stunted with interveinal chlorosis or purpling of leaves and inhibition of roots.

Pinnacle 25DF (DPX M-6316) is used at 0.25 ounce per acre to control lambsquarters, pigweed, smartweed, and velvetleaf. The addition of 1 gallon of 28-0-0 per acre improves velvetleaf control. Tank-mixing with 0.25 ounce of Classic 25DF per acre with Pinnacle can improve control of cocklebur, jimsonweed, and wild sunflower. Add nonionic surfactant at 1 pint per 100 gallons. *Do not use crop oil concentrate.* Pinnacle has less persistence than Classic. Any crop may be planted 45 days after application of Pinnacle alone. Classic recropping intervals apply for the tank-mix.

Pursuit 2E (imazethapyr) is used at 0.25 pint per acre plus surfactant at 1 quart per 100 gallons of spray. Add 1 quart per acre of 28-0-0 or 10-34-0. Most broadleaf weeds should be less than 3 inches tall, but cocklebur and pigweed may be controlled up to 8 inches tall. Lambsquarters, common ragweed, and annual morningglory control may be poor. It may also provide some control of foxtails and shattercane but not volunteer corn. Do not apply Pursuit within 85 days of soybean harvest. Recropping intervals are 4 months after application for wheat, 9.5 months for field corn, and 18 months for other field crops *including grain sorghum.* See Table 8. Do not apply products containing chlorimuron or imazaquin the same year as Pursuit since such combinations increase the potential for injury to subsequent crops.

Scepter (imazaquin) can be used postemergence to control pigweed, cocklebur, wild sunflower and volunteer corn in soybeans. The low rate is 1/3 pint of 1.5E or 1.4 ounces of 70DG. A higher rate is labeled, but rotational guidelines change. Scepter is better on cocklebur and volunteer corn than Pursuit, but Pursuit is better on velvetleaf and shattercane. Use a nonionic surfactant at 2 pints per 100 gallons. Do not apply Scepter within 90 days of soybean harvest. Follow rotational guidelines on the Scepter label or see Table 8. Also see the recrop discussion on Scepter in the preplant or preemergence section.

Rescue (naptalam plus 2,4-DB), a premix of two translocated herbicides, is used at 2 to 3 quarts per acre for midseason control of cocklebur, giant ragweed, and wild sunflower. Apply after soybeans are 14 inches tall or after first bloom. Rescue can be tank-mixed with Blazer or Tackle to control more weeds and provide faster action on the weeds. Add crop oil concentrate or surfactant at the manufacturer's recommended rate. Effectiveness may be reduced if rain occurs within 6 hours. Crop injury often occurs as leaf twisting and drooping tops. Do not apply Rescue to soybeans under stress from drought, disease, or injury from another herbicide. Do not apply Rescue within 60 days of harvest.

Translocated grass herbicides

Poast, Assure, Fusilade, and Option can control many annual and perennial grasses in soybeans (see Table 11). Pursuit also has some postemergence grass control. Grasses should be actively growing (not stressed or injured) and not tillering or forming seedheads. Cultivation within 5 to 7 days before or after application may decrease grass control. Addition of crop oil concentrate is usually specified, especially if the weeds are somewhat droughty or label limitations on weed size are approached.

Rates vary by weed size and species, so consult the label before applying. Rate reductions may be optional on small weeds while rate increases may be needed for larger weeds. Crabgrass, field sandbur, and barnyardgrass control vary with herbicide and size. Control of johnsongrass and quackgrass often requires follow-up applications for control of regrowth. *Volunteer cereals* such as wheat and rye can be controlled by Assure, Fusilade, or Poast if the plants have not tillered or overwintered.

Specified spray volume per acre is 10 to 20 gallons for ground application or 3 to 5 gallons for aerial application. A one-hour rain-free period after application is needed. Avoid drift to sensitive crops such as corn, sorghum, or wheat. Apply before bloom stage of soybeans and at least 80 to 90 days before harvest.

These herbicides do not control broadleaved weeds. Most labels allow tank-mixing with certain broadleaf herbicides, but limitations are made as to rate, timing, and spray coverage. *Check the label before applying grass and broadleaf herbicide tank-mixes or sequences as control of grass weeds may be reduced.*

Poast 1.5E (sethoxydim) is used at 1 pint per acre to control most annual grasses including foxtails, fall panicum, volunteer corn, or shattercane. See label for weed sizes and special rates for smaller or larger weeds. Fertilizer adjuvants are specified for control of volunteer corn and shattercane. Always add 2 pints per acre of Dash or crop oil concentrate. **Poast Plus 1E** has extra additives to improve performance. The rate is 1.5 pints instead of 1 pint per acre to compensate for the change of active ingredients. Poast or Poast Plus can be tank-mixed with Basagran and/or Blazer or Tackle. See the label for more information on rates

Table 11. Soybean Postemergence Herbicides and Their Grass Control

Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	VCN	VCL	JHG	QKG	WSM
Assure	8+	9	9+	9+	9	9	9	10	10	9	9	9	9
Fusilade	8+	8	8	9	8	9	9	10	10	9	9	9	9
Option/Whip	8	7	8+	8+	8	8	–	9	10	–	8	–	8
Poast Plus	9	8	9+	9+	9	9	7	8	8	7	7	7+	8
Pursuit	6	7	7	7+	6	5	4	7	4	3	3	0	2

– = weed not on label or insufficient information.
Note: Annual grasses are BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, VCN = volunteer corn, and VCL = volunteer cereal (wheat, oats, rye).
Perennial grasses are JHG = johnsongrass, QKG = quackgrass, and WSM = wirestem muhly.

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, and 5 = 45 to 55%.

and weed sizes. See "Problem perennial weeds" section for control of perennial grasses.

Assure 0.8E (quizalofop) is used at 14 fluid ounces per acre to control foxtails and fall panicum. Use 10 fluid ounces per acre to control volunteer corn or shattercane. Refer to the label for weed sizes. Add either 1 gallon of crop oil concentrate or 2 quarts of nonionic surfactant per 100 gallons of spray. Assure can be tank-mixed with Basagran or Classic. Refer to the label for rates and weed sizes. See "Problem perennial weeds" section for control of perennial grasses.

Fusilade 2000 1E (fluazifop) is applied at 1.5 pints per acre to control giant foxtail and other annual grasses. Use 0.75 pint per acre for volunteer corn or shattercane. Refer to the label for weed sizes and rates. Add either 1 gallon of crop oil concentrate or 1 quart of nonionic surfactant per 100 gallons of spray. Fusilade can be tank-mixed with Reflex, Tackle, or Blazer. See the label for rates and weed sizes. See "Problem perennial weeds" section for control of perennial grasses.

Option 1E (fenoxaprop) is used at 0.8 pint per acre to control giant foxtail, volunteer corn, or shattercane. Use 1.2 pint per acre for fall panicum or barnyardgrass control. Crop oil concentrate is required for yellow foxtail and crabgrass but is optional for shattercane. See perennial weed section for control of perennial grasses. Option can be tank-mixed with Basagran, Blazer, or Tackle. See the label for instructions.

Roundup (glyphosate) may be applied through rope-wick applicators to control volunteer corn, shattercane, and johnsongrass. Hemp dogbane and common milkweed may also be suppressed. Weeds should be at least 6 inches taller than the soybeans to avoid contact with the crop. Adjust the height so that the wiper contact is at least 2 inches above soybeans. Mix 1 gallon of Roundup with 2 gallons of water for rope-wick applicators. Spot treatment can be made on a spray-to-wet basis using a 2-percent solution of Roundup in water. Motorized spot treatment may provide less complete spray coverage of weeds, so use a 5-percent solution of Roundup. Minimize spray contact with the soybeans.

Soybean harvest aid

Gramoxone Super or Extra (paraquat) may be used for drying weeds in soybeans just before harvest. For indeterminate varieties (most of the varieties planted in Illinois), apply when 65 percent of the seed pods have reached a mature brown color or when seed moisture is 30 percent or less. For determinate varieties, apply when at least one-half of the leaves have dropped and the rest of the leaves are turning yellow.

The rate is 11 to 21 ounces of Gramoxone Super 1.5S or 12.8 ounces of Gramoxone Extra 2.5S. Use the higher rate on cocklebur. The total spray volume per acre is 2 to 5 gallons for aerial application and 20 to 40 gallons for ground application. Add 1 quart of nonionic surfactant per 100 gallons of spray. Do not pasture livestock within 15 days of treatment, and remove livestock from treated fields at least 30 days before slaughter. *Gramoxone is a restricted-use pesticide.*

Problem Perennial Weeds

Perennial weeds are on the increase throughout most of Illinois. Reduced tillage, more restrictive crop rotation practices, and a reduction in competition from annual weeds are the primary causes of the increase.

Perennial weeds are often found in dense localized infestations or lightly scattered within fields. However, even small populations can cause reductions in crop yield, grain quality, and harvesting efficiency and can develop into very serious infestations if left untreated.

Control of most perennials is difficult at best. This is mostly due to the fact that perennials reproduce both by vegetative propagation and by seed. Light tillage, such as the use of a chisel plow or field cultivator, may drag root sections about the field where new shoots emerge and the problem spreads. If tillage is to be beneficial, root sections displaced by tillage must be exposed to the freeze-thaw cycle of winter weather or left on the soil surface to desiccate. Repeated mowings, where possible, or row cultivation can deplete food reserves these plants store in the roots.

Effective control of perennial weeds will often rely on a combination of mechanical control methods and the use of translocated (systemic) herbicides. Tillage and herbicide applications used in combination will weaken the vegetative regeneration of plant parts and suppress seedling development. Since no program is 100 percent effective, elimination of perennial weeds from a single location may take years of treatment. When using systemic herbicides, control of perennials is often more effective when low dosage, multiple treatments are applied. This results in better movement of the herbicide into the roots and a more complete kill of perennial plant parts. Contact herbicides, which do not move within the plant, will not be effective in preventing regrowth from plant roots.

Table 12 lists common herbicides recommended for control or suppression of many perennial weeds. Although not indicated in this table, it should be emphasized that isolation of an infested area is often necessary to effectively treat perennial weeds. This can be done by rotating the affected field to small grains or forage legumes, government set-aside, or to a crop where herbicides or mechanical controls can be used.

With any perennial weed infestation, if the affected area is small enough or if plants are lightly scattered through a field, spot treatment with a 2 percent solution of Roundup (3 oz in 1 gal) in a hand-held sprayer is highly effective. Although Roundup is nonselective and must be kept from contacting desirable vegetation, it can be applied to perennial weeds almost any time they are actively growing and have sufficient foliage to absorb and translocate the herbicide.

Roundup can also be used in rope wick applicators and applied to weeds which exceed the height of the crop by 6 inches or more. For wick applicators dilute 1 gallon of Roundup in 2 gallons of water. Do not till the soil for 5 days before or after any Roundup application.

Following in Table 12 are recommendations for control of many of the most common perennial weeds in Illinois. Be sure to observe all precautions regarding drift and crop injury when applying any of the herbicides mentioned. These precautions can be found on the herbicide labels.

Table 12. Problem Perennial Weeds

Weed	Crop	Herbicide	Remarks
Bindweed	Corn	2,4-D ester 0.5 pt/A or amine 1 pt/A of 3.8 a.e.*	Apply in spring when leaves are fully expanded or apply preharvest after brown silk stage in corn. The ester formulation is perferred. Use drop nozzles when corn is over 8 inches tall.
		Banvel at 0.5 to 1 pt/A	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches, or up to 2 weeks before tassel, whichever comes first.
	Soybeans	Blazer, Cobra, Tackle (rates on label)	Vines may be suppressed by applications. Control can be improved by adding 2 fluid ounces/A of Butyrac 200.
Bigroot morningglory	Corn	2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use on actively growing plants that have sufficient vine growth to which to apply the herbicide (10 to 24 inches).
Canada thistle	Corn	Atrazine at 2 qt + 2 qt	Apply 2 lb a.i. in fall or early spring and follow 10 to 14 days later with tillage. Incorporate second application just prior to planting or apply as posttreatment with crop oil before thistles are 6 inches tall. Plant only corn or sorghum the following year.
		Banvel at 0.5 to 1 pt/A or 2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches or up to 2 weeks before tassel, whichever comes first. Use drop nozzles when corn is over 8 inches tall.
		Laddok 3.5 pt/A	Suppression only. Apply when Canada thistle is 8 to 10 inches tall. Use with 2 pt/A COC.
		Buctril 1.5 pt/A or Buctril/atrazine 2 to 3 pt/A	Suppression only. Apply to weeds from 8 inches tall to the bud stage or up to tassle emergence on corn. Do not add spray additives.
	Corn/Soybeans	Roundup 2 to 3 qt/A	Apply after harvest and prior to tillage in fall. Do not till for 3 days after application. Weeds should be actively growing.
		Basagran 1 qt/A	Will suppress thistle growth. Retreatment 7 to 14 days later with Basagran, or cultivation may be necessary to maintain suppression.

Table 12. Problem Perennial Weeds (continued)

Weed	Crop	Herbicide	Remarks
Common milkweed and Hemp dogbane	Corn	2,4-D amine 1 to 2 pt/A or ester 1 to 2 pt/A of 3.8 a.e.	Apply mid to late season after corn silks have turned brown and plants are actively growing and have adequate foliage.
Honeyvine milkweed	Corn	2,4-D ester 0.5 pt/A or 2,4-D amine 1 pt/A of 3.8 a.e. or Banvel 0.5 to 1 pt/A or 2,4-D + Banvel at half rates	The ester formulation of 2,4-D is preferred; however, a combination of 2,4-D and Banvel may be better than 2,4-D used alone. Check Banvel label for restrictions.
	Soybeans	Blazer, Cobra, Tackle at label rates	May be suppressed by these contact herbicides. Cultivation may be necessary to improve control.
Jerusalem artichoke	Corn	Banvel 0.5 to 1 pt/A or Banvel + 2,4-D at half rates	Treat weeds when they are 8 to 16 inches tall. Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches or up to 2 weeks before tassel whichever comes first. Use drop nozzles when corn is over 8 inches tall.
		Atrazine 2 qt + 2 qt	Apply 2 lb a.i. in fall or early spring and follow in 10 to 14 days with tillage. Incorporate a second application just prior to planting. Plant only corn or sorghum the following year.
	Soybeans	Pursuit at 4 fluid oz/A Classic at 0.75 oz/A	Pursuit should be applied to plants that are 6 to 10 inches tall and Classic to plants less than 8 inches tall. Small weeds just emerging may have sufficient root/tuber reserves to begin regrowth after treatment and a cultivation may be required. Use a surfactant at 0.25 percent, or 1 qt in 100 gal.
Swamp smartweed	Corn	Banvel 0.5 to 1 pt/A	Use the higher rate on corn shorter than 8 inches. Use the lower rate on taller corn up to 36 inches or up to 2 weeks before tassel, whichever comes first, or on sandy soils. Use drop nozzles if the corn is more than 8 inches tall.
Yellow nutsedge	Corn	Sutan+, Genate Plus, Eradicane (labeled rate for soil)	Apply preplant incorporated.
		Laddok 3.5 pt/A	Suppression only. Add 2 pt/A COC.
	Corn/Soybeans	Lasso, Dual	Use higher rate for soil type and incorporate thoroughly.
	Soybeans	Scepter 2/3 pt/A	Thoroughly incorporate for best control.
		Basagran 2 pt/A	Apply 1.5 to 2 pt/A when plants are 6 to 8 inches tall. Reapply 7 to 10 days later if needed. Add 2 pt/A COC with each application.
Rhizome or seedling Johnsongrass	Soybeans	Assure 1.25 pt/A	Apply 1.25 pt/A of Assure to johnsongrass when 10 to 24 inches tall. For regrowth apply additional 7/8 pt/A to regrowth 6 to 10 inches tall.
		Poast 1.0 pt/A	Apply 1.0 pt/A of Poast to johnsongrass 15 to 25 inches tall. Apply 1 pt/A Poast to regrowth. Use Dash or COC and 28-0-0 (UAN).
		Fuslilade 1.5 pt/A	Fusilade can be used at 1.5 pt/A on 8 to 18 inch johnsongrass and applied to 6 to 12 inch regrowth at 1 pt/A. Use COC or nonionic surfactant.
		Option 1.2 pt/A	Apply to 10 to 20 inch johnsongrass. Do not add crop oil concentrate. Apply 0.8 pt/A to regrowth.

Table 12. Problem Perennial Weeds (continued)

Weed	Crop	Herbicide	Remarks
Quackgrass	Corn	Atrazine 2 qt + 2 qt	Apply 2 lb a.i. in fall or early spring and follow 10 to 14 days later with tillage. Incorporate second application just prior to planting. Plant only corn or sorghum the following year.
		Eradicane Extra 4 qt/A or Eradicane 6.7E 7.3 pt/A	A lighter rate may be used on lighter infestations. Use a tank-mix with atrazine to improve control.
	Corn/Soybeans	Roundup 1 to 2 qt/A	Apply prior to spring tillage or after harvest in the fall. Do not till for 3 days before or after application. Weeds should be actively growing and greater than 8 inches tall.
	Soybeans	Assure 1.25 to 2.25 pt/A	Apply 1.25 pt/A of Assure when quackgrass is 6 to 10 inches tall. For regrowth apply ⅞ pt/A when quackgrass is 4 to 8 inches tall.
		Fusilade 1.5 pt/A	Fusilade can be used at 1.5 pt/A on 6 to 10 inches quackgrass and applied to regrowth at 1 pt/A. Use COC or nonionic surfactant.
		Poast 1.5 pt/A	Apply 1.5 pt/A of Poast to quackgrass 6 to 8 inches tall and 1 pt/A to regrowth. Use Dash or COC and 28-0-0 (UAN).
Wirestem muhly	Soybeans	Assure 1.25 pt/A	Apply 1.25 pt/A of Assure when wirestem is 4 to 6 inches tall. For regrowth, apply ⅞ pt/A.
		Fusilade 1.5 pt/A	Fusilade can be used at 1.5 pt/A on 4 to 12 inches wirestem and applied to regrowth at 1.5 pt/A. Use COC or nonionic surfactant.
		Poast 1.25 pt/A	Apply 1.25 pt/A to wirestem up to 6 inches tall and 1.25 pt/A to regrowth. Use Dash or COC.
		Option 1.2 pt/A	Apply 1.2 pt/A of Option to 3 to 6 inches wirestem muhly. Use COC at 1 qt/A.

[a] a.e. = acid equivalent. If not 3.8 lb/gal, use equivalent amount.

Prepared by M.D. McGlamery, professor of weed science, Dave R. Pike, agronomist, Ellery L. Knake, professor of weed science, William E. Curran, associate agronomist, and C. Diane Anderson, Extension assistant, all at the University of Illinois; with the assistance of Rex Liebl, assistant professor of agronomy at the University of Illinois, and George Kapusta, professor of plant and soil science, Southern Illinois University, Carbondale.

This guide is based in part upon research conducted by Loyd A. Wax, agronomist, USDA, and professor of weed science, and by E.W. Stoller, plant physiologist, USDA, and professor of agronomy, both at the University of Illinois. The assistance of industry representatives is also gratefully acknowledged.

1990 Weed Control in Small Grains, Pastures, and Forages

Good weed control is necessary for maximum production of high-quality small grains, pastures, and forages in Illinois. When properly established, these crops can usually compete effectively with weeds so that the need for herbicide applications is minimized. Weeds, however, can sometimes become significant problems and warrant control. For example, wild garlic is considered the worst weed problem in wheat in southern Illinois. Because its life cycle is similar to that of winter wheat, wild garlic can establish itself with the wheat, grow to maturity, and produce large quantities of bulblets by wheat-harvest time. Economic considerations make it necessary to attempt some control of wild garlic in winter wheat.

In pastures, woody and herbaceous perennials can become troublesome. Annual grasses and broadleaf weeds such as chickweed and henbit may cause problems in hay crops. Through proper management, many of these weed problems can be controlled effectively.

Several herbicide labels carry the following groundwater warnings under either the environmental hazard or the groundwater advisory section. "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface." See Table 1 for a list of herbicides that carry this warning.

Small grains

Good weed control is critical for maximum production of high-quality small grains. Often, weed problems can be dealt with before the crop is established. For example, many broadleaf weeds are controlled effectively in the late fall after corn or soybean harvest with **2,4-D, Banvel** (dicamba), or **Roundup** (glyphosate).

Tillage helps control weeds. Although generally limited to preplant and postharvest operations, tillage can destroy many annual weeds and help suppress certain perennials. Good cultural practices such as proper seeding rate, optimum soil fertility, and timely planting help to ensure the establishment of an excellent stand and a crop that is better able to compete with weeds.

Winter annual grasses such as downy brome and cheat are very competitive in winter wheat. Illinois wheat producers are often limited to preplant tillage operations for control of these species as few herbicides have label clearances for annual grass control in winter wheat. If a severe infestation of downy brome or cheat exists, planting an alternative crop or spring crop may be best for that field.

A decision to use postemergence herbicides for broadleaf weed control in small grains should be based on several considerations:

1. *Nature of the weed problem.* Identify the species present and consider the severity of the infestation. Also note the size of the weeds. Weeds are usually best controlled while small.
2. *Stage of the crop.* Most herbicides are applied after full tiller until the boot stage. Do not apply herbicides from the boot stage to the hard-dough stage of most small grains. (See Figure 1 for a description of growth stages of small grains.)
3. *Presence of a legume underseeding.* Usually 2,4-D ester formulations and certain other herbicides listed

Prepared by W. S. Curran, associate agronomist, M. D. McGlamery, professor of weed science, E. L. Knake, professor of weed science, D. R. Pike, agronomist, and C. D. Anderson, Extension assistant.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
Urbana, Illinois Circular 1278-90 (revised annually) October 1989

Table 1. List of Herbicides, Formulations, and Special Statements

Trade name	Common name	Formulation	Restricted use	Ground water advisory
Balan 1.5E	benefin	1.5lb/gal	no	no
Banvel	dicamba	4 lb/gal	no	no
Buctril	bromoxynil	2 lb/gal	yes	no
Butyrac 200	2,4-DB	2 lb/gal	no	no
Butyrac Ester	2,4-DB	2 lb/gal	no	no
Crossbow	2,4-D + triclopyr	2 + 1 lb/gal	no	no
Eptam 7E	EPTC	7 lb/gal	no	no
Eptam 10G	EPTC	10%	no	no
Genep 7E	EPTC	7 lb/gal	no	no
Gramoxone Extra	paraquat	2.5 lb/gal	yes	no
Gramoxone Super	paraquat	1.5 lb/gal	yes	no
Harmony Extra 75DF	DPX-R9674	75%	no	no
Kerb 50W	pronamide	50%	?	no
Lexone 4L	metribuzin	4 lb/gal	no	yes
Lexone DF	metribuzin	75%	no	yes
MCPA	MCPA	several	no	no
Option	fenoxaprop	1 lb/gal	no	no
Poast	sethoxydim	1.5 lb/gal	no	no
Prowl	pendimethalin	4 lb/gal	no	no
Roundup	glyphosate	3 lb ae/gal	no	no
Sencor 4L	metribuzin	4 lb/gal	no	yes
Sencor DF	metribuzin	75%	no	yes
Sinbar	terbacil	80%	no	no
Spike 20P	tebuthiuron	20%	no	no
Spike 40P	tebuthiuron	40%	no	no
Treflan	trifluralin	4 lb/gal	no	no
Velpar L	hexazinone	2 lb/gal	no	no
2,4-D amine	2,4-D	several	no	no
2,4-D ester	2,4-D	several	no	no

Table 2. Effectiveness of Herbicides on Weeds in Small Grains

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labelled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions, or other variables. Weed control rating: 10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control.

Weed	Susceptibility to herbicide				
	2,4-D	MCPA	Banvel	Buctril	Harmony Extra
Winter annual					
Buckwheat, wild	5	8	10	9	8
Chickweed, common	5	5	6	6	9
Henbit	5	5	6	8	9
Horseweed (marestail)	8	8	10	6	7
Lettuce, prickly	10	9	8	6	8
Mustard spp., annual	10	10	6	9	9
Pennycress, field	10	10	6	8	9
Shepherdspurse	10	10	8	8	9
Summer Annual					
Lambsquarters, common	10	10	10	10	8
Pigweed spp.	10	10	10	7+	9
Ragweed, common	10	9	10	9	0
Ragweed, giant	10	9	10	8	0
Smartweed, Pennsylvania	6	7	9	9	9
Perennial					
Dandelion	9	8	8	0	6
Garlic, wild					
aerial bulblets	6[a]	5	5	0	9
underground bulbs	0	0	0	0	5

[a] 2,4-D ester at maximum use rate.

Table 3. Weed Control in Small Grains

Herbicide	Broadcast rate/acre	Remarks	Restrictions
Oats and wheat			
2,4-D, 3.8 lb a.i. (amine)	½ to 1½ pt	Winter wheat more tolerant than oats. Apply in spring after full tiller but before boot stage. Do not treat in fall. Use lower rate of amine if underseeded with legume. Some legume damage may occur. May be used as preharvest treatment at 1 to 2 pints per acre during hard-dough stage.	Do not forage or graze within 2 weeks after treatment. Do not feed treated straw to livestock following a preharvest treatment.
MCPA (amine)	¼ to 3 pt	Less likely than 2,4-D to damage oats and legume underseeding. Apply from 3-leaf stage to boot stage. Rate varies with crop and weed size and presence of legume underseeding.	Do not graze dairy animals on treated areas for 7 days after treatment.
Banvel, 4 lb a.i.	4 fl oz	Do not apply to small grains with legume underseeding. In fall-seeded wheat, apply before jointing stage. In spring-seeded oats, apply before oats exceed 5-leaf stage.	Do not graze or harvest for dairy feed before ensilage (milk) stage.
Buctril 2E	1 to 2 pt	Apply Buctril alone to fall-seeded small grains in the fall or spring, but before the boot stage. Weeds are best controlled before the 3- to 4-leaf stage. Buctril may be applied at 1 to 1½ pints per acre to small grains underseeded with alfalfa.	Do not graze treated fields for 30 days after application.
Wheat only			
2,4-D, 3.8 lb a.i. (ester)	½ to ¾ pt	Do not apply to wheat with legume underseeding. Apply in spring after full tiller but before boot stage. For preharvest treatment, apply 1 to 2 pints per acre during hard-dough stage. For control of wild garlic or wild onion, apply 1 to 2 pints in the spring when wheat is 4 to 8 inches high, after tillering but before jointing; these rates may injure the crop.	Do not forage or graze within 2 weeks after treatment. See current label for additional restrictions.
Harmony Extra 75DF	0.3 to 0.6 oz	Apply to the crop after the 2-leaf stage, but before the third node is detectable. Wild garlic should be less than 12 inches tall, with 2 to 4 inches of new growth. Annual broadleaf weeds should be past the cotyledon stage, actively growing, and less than 4 inches tall or across. Nonionic surfactant at 0.25% v/v should be included in the spray mixture. When liquid fertilizer is used as the carrier, use 1/16-¼% v/v surfactant. Temporary stunting and yellowing may occur when Harmony Extra is applied using liquid fertilizer solution as the carrier. These symptons will be intensified with the addition of surfactant. Without surfactant addition, wild garlic control may be erratic.	Do not plant to any crop other than wheat or barley within 30 days after application. Do not apply to cereals underseeded with legumes.

in Table 3 should not be applied because they may damage the legume underseeding.

4. *Herbicide activity.* Determine crop tolerance and weed susceptibility to herbicides by referring to Tables 2 and 3. The lower rates in Table 3 are for more easily controlled weeds and the higher rates for the more difficult to control species. Tank-mixes may broaden the weed spectrum and thereby improve control; check the herbicide label for registered combinations.
5. *Economic justification.* Consider the cost of the treatment in terms of potential benefits such as the value of increased yield, improved quality of grain, and ease of harvesting the crop.

Table 3 outlines current suggestions for weed control options in wheat and oats, the two small grains most commonly grown in Illinois. Always consult the herbicide label for specific information about the use of a given product.

For annual broadleaf weeds postemergence herbicides such as **2,4-D, MCPA, Banvel,** and **Buctril** (bromoxynil) can provide good control of susceptible species (Table 2). Herbicides must be applied during certain growth stages of the crop to avoid crop injury and for optimum weed control. Refer to Figure 1 for a description of the growth stages of small grains.

Some perennial broadleaf weeds may not be controlled satisfactorily with the low herbicide rates used in small grains; and higher rates are not advisable because they can cause serious injury to crops. To control perennial weeds, translocated herbicides such as **2,4-D, Banvel,** or **Roundup,** in combination with tillage after small grain harvest or after soybean harvest but before establishing small grains, may be the best approach.

Wild garlic continues to be a serious weed problem in winter wheat. **Harmony Extra** (DPX-R9674), applied in the spring at 0.3 to 0.6 ounce of 75 DF per acre, effectively controls wild garlic aerial bulblets and some underground bulbs as well. **Harmony Extra** also helps control chickweed, henbit, common lambsquarters, smartweed, and several species of mustard. See Tables 2 and 3 for additional information on controlling weeds in small grains.

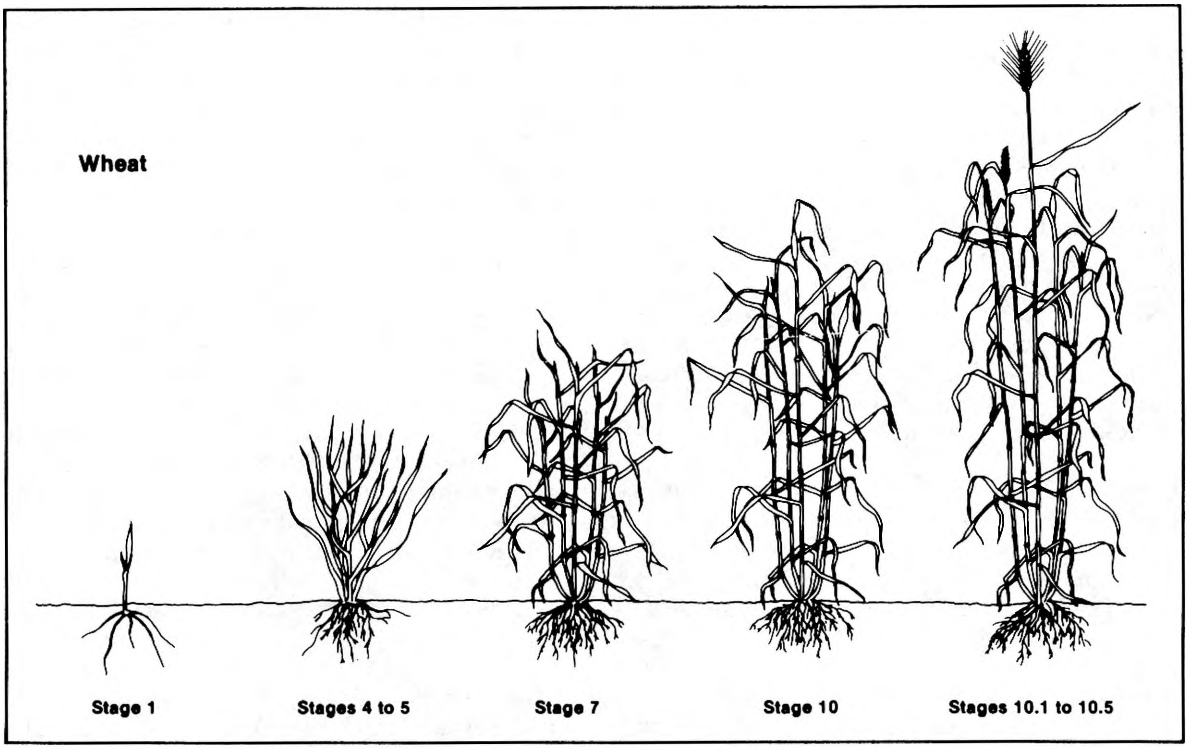


Figure 1. Growth stages of small grains.

Seedling

Stage 1. The coleoptile, a protective sheath that surrounds the shoot, emerges. The first leaf emerges through the coleoptile, and other leaves follow in succession from within the sheath of the previously emerging leaf.

Tillering

Stages 2 to 3. Tillers (shoots) emerge on opposite sides of the plant from buds in the axils of the first and second leaves. The next tillers may arise from the first shoot at a point above the first and second tillers or from the tillers themselves. This process is repeated until a plant has several shoots.

Stages 4 to 5. Leaf sheaths lengthen, giving the appearance of a stem. The true stems in both the main shoot and in the tillers are short and concealed within the leaf sheaths.

Jointing

Stage 6. The stems and leaf sheaths begin to elongate rapidly, and the first node (joint) of the stem is visible at the base of the shoot.

Stage 7. Second node (joint) of stem is visible. The next-to-last leaf is emerging from within the sheath of the previous leaf but is barely visible.

Stage 8. Last leaf, the "flag leaf," is visible but still rolled.

Stage 9: Preboot stage. Ligule of flag leaf is visible. The head begins to enlarge within the sheath.

Stage 10: Boot stage. Sheath of flag leaf is completely emerged and distended because of enlarging but not yet visible head.

Heading

Stages 10.1 to 10.5. Heads of the main stem usually emerge first, followed in turn by heads of tillers in order of their development. Heading continues until all heads are out of their sheaths. The uppermost internode continues to lengthen until the head is raised several inches above the uppermost leaf sheath.

Flowering

Stages 10.5.1 to 10.5.3. Flowering progresses in order of head emergence. Unpollinated flowers result in barren kernels.

Stage 10.5.4: Premilk stage. Flowering is complete. The inner fluid is abundant and clear in the developing kernels of the flowers pollinated first.

Ripening

Stage 11.1: Milk stage. Kernel fluid is milky white because of accumulating starch.

Stage 11.2: Dough stage. Kernel contents are soft and dry (doughy) as starch accumulation continues. The plant leaves and stems are yellow.

Stage 11.3. The kernel is hard, difficult to divide with the thumbnail.

Stage 11.4. Ripe for cutting. Kernel will fragment when crushed. The plant is dry and brittle.

Grass pastures

Unless properly managed, broadleaf weeds can become a serious problem in grass pastures. They can compete directly with forage grasses and reduce the nutritional value and longevity of the pasture. Certain species, such as white snakeroot and poison hemlock, are also poisonous to livestock and may require special consideration.

Perennial weeds are probably of greatest concern. They can exist for many years, reproducing from both seed and underground parent rootstocks. Occasional mowing or grazing helps control certain annual weeds, but perennials can grow back from underground root reserves unless long-term control strategies are implemented.

Certain biennials can also flourish in grass pastures. The first year, they exist as a prostrate rosette, so that even close mowing does little to control their growth. The second year, biennials produce a seedstalk and a deep taproot. If these weeds are grazed or mowed at this stage, root reserves can sometimes enable the plant to grow again, thereby increasing its chance of surviving to maturity.

In general, the use of good cultural practices such as maintaining optimum soil fertility, rotational grazing, and periodic mowing can help keep grass pastures in good condition and more competitive with weeds. Where broadleaf weeds become troublesome, however, **2,4-D** or **Banvel** may be used. **Roundup** may also be used as a spot treatment, and **Crossbow** (2,4-D plus triclopyr) is labeled for control of broadleaf and woody plant species in permanent grass pastures. Certain formulations of **Spike** (tebuthiuron) may also be used in grass pastures for brush and woody plant control. (See Tables 4 and 5 for additional information.)

Proper identification of target weed species is important. As shown in Table 4, weeds vary in their susceptibility to herbicides. Timing of herbicide application may also affect the degree of weed control. Annuals and biennials are most easily controlled while young and relatively small. A fall or early spring treatment works best if biennials or winter annuals are the main weed problem. Summer annuals are most easily controlled in the spring or early summer. Apply translocated herbicides to control established perennials when the weeds are in the bud to bloom stage. Perennials are most susceptible at this reproductive phase because translocated herbicides can move downward with food reserves to the roots, potentially killing the entire plant.

For control of woody brush, apply **2,4-D, Banvel,** or **Crossbow** when the plants are fully leafed and actively growing. Where regrowth occurs, a second treatment may be needed in the fall. During the dormant season, oil-soluble formulations of **2,4-D,**

Table 4. Effectiveness of Herbicides on Weeds in Grass Pastures

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labelled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions, or other variables. Weed control rating: 10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control.

Weed	Susceptibility to herbicide			
	2,4-D	Banvel	Crossbow	Roundup[a]
Winter Annual				
Horseweed (marestail)	9	10	10	10
Pennycress, field	10	8	9	10
Summer annual				
Ragweed, common	10	10	10	10
Ragweed, giant	10	10	10	10
Biennial				
Burdock, common	10	10	10	9
Hemlock, poison	9	10	10	9
Thistle, bull	10	10	10	10
Thistle, musk	10	9	9	10
Perennial[b]				
Daisy, oxeye	8	10	10	9
Dandelion	10	8	10	8
Dock, curly	7	10	10	9
Goldenrod spp.	8	9	8	10
Hemlock, spotted water	9	10	10	9
Ironweed	8	10	9	10
Milkweed, common	6	8	8	8
Nettle, stinging	9	9	9	9
Plantain spp.	10	8	10	9
Rose, multiflora[c]	8	9	10	9
Snakeroot, white	8	9	9	8
Sorrel, red	5	10	10	8
Sowthistle, perennial	8	9	10	9
Thistle, Canada	8	9	9	8

[a] Spot treatment.
[b] Perennial weeds may require more than one application.
[c] Spike is also an effective herbicide for multiflora rose control (weed susceptibility = 10).

Table 5. Broadleaf Weed Control in Grass Pastures

Herbicide	Rate/acre	Remarks	Restrictions
2,4-D, 3.8 lb a.i. (amine or low-volatile ester)	2 to 4 pt	Broadleaf weeds should be actively growing. Higher rates may be needed for less susceptible weeds and some perennials. Spray bull or musk thistles in the rosette stage (spring or fall) while they are actively growing. Spray perennials such as Canada thistle in the bud stage. Spray susceptible woody species in spring when leaves are fully expanded.	Do not graze dairy animals within 7 days after treatment. Do not apply to newly seeded areas or to grass when it is in boot to milk stage. Be cautious of spray drift.
Banvel, 4 lb a.i.	Annuals: ½ to 1½ pt Biennials: ½ to 3 pt Perennials: 1 to 2 pt (suppression) Perennials: 1 to 6 qt (control) Woody brush: 1 to 2 pt (suppression) Woody brush: 1 to 8 qt (control)	Use lower rates for susceptible annuals when they are small and actively growing and for susceptible biennials in the early rosette stage. Use higher rates for larger weeds, for less susceptible weeds, for established perennials in dense stands, and for certain woody brush species.	Refer to label for specific timing restrictions for lactating dairy animals. Remove meat animals from treated areas 30 days before slaughter. Be cautious of spray drift.
Crossbow	Annuals: 1-2 qt Biennials and herbaceous perennials: 2 to 4 qt Woody perennials: 6 qt	Apply to foliage during warm weather when brush and broadleaf weeds are actively growing. When applying as a spot spray, thoroughly wet all foliage. See herbicide label for more specific rate recommendations.	Remove livestock from treated forage at least 3 days before slaughter during the year of treatment. Do not graze lactating dairy animals on treated areas for one year following treatment. Do not harvest grass for hay from treated areas for one year following treatment. Be cautious of spray drift.
Roundup	2% solution (spot treatment)	Controls a variety of herbaceous and woody brush species such as multiflora rose, brambles, poison ivy, quackgrass. Spray foliage of target vegetation completely and uniformly, but not to point of runoff. Avoid contact with desirable nontarget vegetation. Consult label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Allow 14 days after application before grazing or harvesting forage.
Spike 20P Spike 40P	10 to 20 lb 5 to 10 lb	For control of brush and woody plants in rangeland and grass pastures. Requires sufficient rainfall to move herbicide into root zone. May kill or injure desirable legumes and grasses where contact is made. Injury is minimized by applying when grasses are dormant.	Do not apply on or near field crops or other desirable vegetation. Do not apply where soil movement is likely. Grazing allowed in areas treated with 20 lb or less Spike 20P and 10 lb or less Spike 40P. At these rates, grass may be cut for hay 1 year after application. Refer to label for additional restrictions.

Banvel or **Crossbow** may be used in fuel oil. **Spike** controls many woody perennials and should be applied to the soil in the spring. **Spike** requires rainfall to move it into the root zone of target species.

The weed control options in grass pastures are shown in Table 5. Be cautious with any pesticide and always consult the herbicide label for specific information about the use of a given product.

Forage legumes

Weed control is very important in managing forage legumes. Weeds can severely reduce the vigor of legume stands and thus reduce yield and forage quality. Good management begins with weed control practices that prevent weeds from becoming serious problems.

Establishment

To minimize problems, prepare the seedbed properly so that it is firm and weed-free. Select an appropriate legume variety. If you use high-quality seed and follow the recommendations for liming and fertility, the legume crop may crowd out many weeds and reduce the need for herbicides.

In fields where companion crops such as oats are used to reduce weed competition, seed the small grain at half the rate for grain production to ensure that the legumes will become established with minimum stress. If the legume is seeded without a companion crop (direct seeded), the use of an appropriate herbicide is suggested.

Preplant incorporated herbicides. Balan (benefin) and **Eptam** or **Genep** (EPTC) are registered for preplant

Table 6. Weed Control in Forages

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
PURE LEGUME FORAGES Seedling year					
Balan 1.5EC	Alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	Preplant incorporated	3 to 4 qt	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on soils high in organic matter.
Eptam 7E,10G or Genep 7E	Alfalfa, birdsfoot trefoil, lespedeza, clovers	Preplant incorporated	3½ to 4½ pt 30 lb (10G)	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on white Dutch clover.
Buctril 2E	Alfalfa only	Postemergence	1 to 1½ pt	Apply in the fall or spring to seedling alfalfa with at least 2 trifoliate leaves. Apply to weeds at or before the 4-leaf stage or 2 inches in height (whichever is first). May be tank-mixed with 2,4-DB for improved control of kochia and pigweed.	A restricted-use herbicide. Do not apply when temperatures are likely to exceed 70°F at application or for the 3 days following application or when the crop is stressed. Do not add a surfactant or crop oil. Do not harvest or graze spring-treated alfalfa within 30 days and fall-treated alfalfa within 60 days following treatment (60 days if tank-mixed with 2,4-DB).
Butyrac 200 or Butyrac Ester	Alfalfa, birdsfoot trefoil, ladino clover, red clover, alsike clover, white clover	Postemergence	1 to 3 qt (amine) 2 to 4 pt (ester)	Use amine or ester formulation when weeds are less than 3 inches tall or less than 3 inches across if rosettes. Use higher rates for seedling smartweed or curly dock.	Do not harvest or graze for 60 days following treatment. Do not use on sweet clover.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Postemergence	1 to 3 lb	In fall-seeded legumes, apply after legumes have reached trifoliate stage. In spring-seeded legumes, apply next fall.	Do not graze or harvest for 120 days following application.
Poast 1.5E	Alfalfa only	Postemergence	¾ to 1½ pt	Alfalfa is tolerant of Poast at all stages of growth. Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB harvest and grazing restrictions.	Do not apply Poast within 7 days of grazing, feeding, or harvesting undried forage, or within 20 days of harvesting dry hay. Do not apply more than a total of 5 pints of Poast per acre in one season. Apply by ground equipment only.
Established stands					
Butyrac 200	Alfalfa only	Growing	1 to 3 qt (amine)	Spray when weeds are less than 3 inches tall or less than 3 inches wide if rosettes. Fall treatment of fall-emerged weeds may be better than spring treatment.	Do not harvest or graze for 30 days following application. Do not apply to sweet clover.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Growing or dormant	1 to 3 lb	Apply in the fall after last cutting, when weather and soil temperatures are cool.	Do not harvest or graze for 120 days.

incorporation for legumes that are not seeded with grass or small-grain companion crops. These herbicides will control most annual grasses and some broadleaf weeds. In fall plantings, the weeds controlled include winter annuals such as downy brome and cheat. In spring legume plantings, the summer annual weeds controlled include foxtails, pigweeds, lambsquarters, crabgrass, and fall panicum.

Eptam or **Genep** can help suppress johnsongrass and quackgrass seedlings, yellow nutsedge, and shattercane, in addition to controlling many annual grasses and some broadleaf weeds. Neither one will effectively control mustards, smartweed, or established perennials. **Balan, Eptam,** and **Genep** *must* be thoroughly incorporated soon after application to avoid herbicide loss. They should be applied shortly before the legume is seeded, so they remain effective as long as possible into the growing season.

Table 6. Weed Control in Forages (continued)

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
Sencor or Lexone	Alfalfa and alfalfa-grass mixtures	Dormant	¾ to 2 pt (4L) ½ to 1⅓ lb (75 DF)	Apply once in the fall or spring before new growth starts. Rate is based upon soil type and organic-matter content. Higher rates may injure grass component.	Do not use on sandy soils or soils with pH greater than 7.5. Do not graze or harvest for 28 days.
Sinbar 80W	Alfalfa only	Dormant	½ to 1½ lb	Apply once in the fall or spring before new growth starts. Use lower rates for coarser soils.	Do not use on sandy soils with less than 1% organic matter. Do not plant any crop for 2 years.
Velpar L	Alfalfa only	Dormant	1 to 3 qt	Apply in the fall or spring before new growth exceeds 2 inches in height. Can also be applied to stubble after hay crop removal but before regrowth exceeds 2 inches.	Do not plant any crop except corn within 2 years of treatment. Corn may be planted 12 months after treatment, provided deep tillage is used. Do not graze or harvest for 30 days.
Poast 1.5E	Alfalfa only	Postemergence	¾ to 1½ pt	Alfalfa is tolerant of Poast at all stages of growth. Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB grazing and harvest restrictions.	Do not apply Poast within 7 days of grazing, feeding, or harvesting undried forage, or within 20 days of harvesting dry hay. Do not apply more than a total of 5 pints of Poast per acre in one season. Apply by ground equipment only.
Gramoxone Extra	Alfalfa only	Dormant Between cutting	1½ to 2 pt 12.8 fl oz	For dormant season, apply after last fall cutting or before spring growth is 1 inch tall. Weeds should be succulent and growing at the time of application. Between cutting treatments should be applied immediately after hay removal within 5 days after cutting. Weeds germinating after treatment will not be controlled. Add surfactant as label indicates.	A restricted-use herbicide. Do not apply if fall regrowth following the last fall cutting is more than 6 inches tall. Do not cut, harvest, or graze for 60 days following a dormant season application and for 30 days between cutting applications.
Roundup	Alfalfa, clover, and alfalfa or clover-grass mixtures	Growing	2% solution (spot treatment)	Apply to actively growing, susceptible weeds. Avoid contact with desirable, nontarget vegetation because damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.	No more than $\frac{1}{10}$ of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Do not graze or harvest for 14 days.

Weeds that emerge during crop establishment should be evaluated for their potential to become problems. If they do not reduce the nutritional value of the forage or if they can be controlled by mowing, they should not be the primary target of a postemergence herbicide. For example, winter annual weeds do not compete vigorously with the crop after the first spring cutting. Unless they are unusually dense or production of weed seed becomes a concern, these weeds may not be a significant problem. Some weeds such as dandelions are palatable and may not need to be controlled if the overall legume stand is dense and healthy; but undesirable weeds must be controlled early to prevent their establishment.

Postemergence herbicides. Poast (sethoxydim) may be applied to seedling alfalfa for control of annual and some perennial grass weeds after weed emergence. Grasses are more easily controlled when small, and alfalfa is tolerant to **Poast** at all stages of growth. **Butyrac** (2,4-DB) controls many broadleaf weeds and may be applied postemergence in many seedling forage legumes. **Buctril** (bromoxynil) may also be used to control broadleaf weeds in seedling alfalfa. Be sure to apply Buctril while weeds are small. (See Table 7 for specific weed control ratings.)

Established legumes

The best weed control in established forage legumes is maintenance of a dense, healthy stand via proper management techniques. Chemical weed control in

Table 7. Effectiveness of Herbicides on Weeds in Legume and Legume-Grass Forages

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labelled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions, or other variables. Weed control rating: 10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control.

Weed	Balan	Buctril	Butyrac	Genep/ Eptam	Gramox- one	Kerb	Poast	Round- up[a,b]	Sencor/ Lexone[a]	Sinbar	Velpar
Winter annual											
Brome, downy	9	0	0	9	9	9	9	9	9	9	8
Chickweed, common	8	6	6	7	9	8	0	10	9	9	9
Henbit	5	8	6	9	9	8	0	8	9	9	8
Mustard, wild	0	8	10	6	9	5	0	9	9	9	9
Pennycress, field	0	9	9	6	9	5	0	10	9	9	9
Shepherdspurse	0	9	9	7	9	5	0	9	9	9	9
Summer annual											
Barnyardgrass	9	0	0	9	8	8	10	10	6	6	7
Crabgrass spp.	9	0	0	9	6	8	10	9	5	7	7
Foxtail spp.	9	0	0	9	9	8	10	10	6	7	7
Lambsquarters, common	9	10	8	9	9	6	0	9	9	9	9
Nightshade spp.[c]	0	9	8	8	9	6	0	9	5	6	6
Panicum, fall	9	0	0	9	9	6	10	10	6	6	6
Pigweed sp.	9	8	8	9	9	6	0	10	9	8	9
Ragweed, common	0	9	9	5	9	5	0	9	8	8	8
Smartweed, Pennsylvania	0	9	6	5	9	5	0	9	9	8	8
Perennial											
Dandelion	0	0	8	0	0	0	0	8	7	6	8
Dock, curly	0	0	5	0	0	0	0	9	6	6	6
Nutsedge, yellow	0	0	0	8	0	0	0	7	0	0	0
Orchardgrass	5	0	0	6	5	7	6	8	5	5	6
Quackgrass	5	0	0	8	5	8	7	9	5	5	5

[a] Lexone, Sencor, and Roundup are labelled for use in mixed legume-grass forages. No other herbicides are cleared for this use.
[b] Spot treatment.
[c] Control of different species may vary.

established forage legumes is often limited to late fall or early spring applications of herbicide. **Sencor** or **Lexone** (metribuzin), **Sinbar** (terbacil), and **Velpar** (hexazinone) are applied after the last cutting in the fall or in the early spring. These herbicides control many broadleaf weeds and some grasses, too. **Kerb** (pronamide) is used for grass control and is applied in the fall after the last cutting. **2,4-DB** controls many broadleaf weeds in established alfalfa; **2,4-DB** should be applied when the weeds are small and actively growing. Refer to Tables 6 and 7 for additional remarks and weed control suggestions.

Once grass weeds have emerged, they are particularly difficult to control in established alfalfa. **Poast** herbicide may be used in established alfalfa for control of annual and some perennial grasses. Optimum grass control is achieved if **Poast** is applied when grasses are small and before the weeds are mowed.

Table 6 outlines current suggestions for weed control options in legume forages. The degree of control will often vary with weed size, application rate, and environmental conditions. Be sure to select the correct herbicide for the specific weeds to be controlled (Table 7). Always consult the herbicide label for specific information about the use of a given product.

Acreage Conservation Reserve Program

The Acreage Conservation Reserve Program (ACR) continues to occupy substantial farmland in Illinois. Investing in good weed control on ACR land will help alleviate some problem weeds when rotating back to row crops. For example, perennial broadleaf weeds such as hemp dogbane and common milkweed may be controlled or suppressed under small-grain production or when a perennial grass or legume species is grown. In addition, mowing or alternative herbicide options may be available. Whether using tillage, mowing, herbicides, or combinations, the best approach is to remain flexible and utilize cost-effective methods that fit your weed problems and management system.

Clover, alfalfa, or other forage legumes may be one of the best options for ACR acres. The cover helps conserve soil, improves soil structure, and adds nitrogen. Clover and alfalfa can be very economical, particularly if grown for at least two consecutive years. The use of a herbicide for legume establishment can allow a vigorous legume stand and alleviate the need for weed control measures later. If annual broadleaf weeds become a problem, applying **2,4-DB** or mowing is another helpful option. Herbicides for use on forage legumes on ACR acres include those registered for commercial production fields and are listed in Table 6. In addition, **Treflan** (trifluralin) or **Prowl** (pendimethalin) may be used preplant incorporated to control annual grasses and some small-seeded broadleaf weeds. Some stand reduction may occur with **Treflan** or **Prowl**, but good weed control can compensate to allow for excellent establishment of the legume. **Fusilade** (fluazifop), **Option** (fenoxaprop), and **Poast** (sethoxidim) may be used for grass control postemergence on forage legumes on ACR land. With many of these products, haying and grazing are not allowed, therefore be sure to follow all restrictions imposed by the pesticide label.

Oats are commonly grown as a cover crop on set-aside acres. Oat seed is inexpensive and easy to obtain. If the Agricultural Stabilization and Conservation Service (ASCS) does not require clipping before seed maturity, oats can reseed themselves for fall cover. Wheat, rye, and barley are other small-grain cover crop possibilities.

Sowing clean oat, wheat, rye, or barley seed is the first step to minimizing weed problems. Small grains generally provide relatively good cover until they mature or the area is mowed; then weeds can soon proliferate. However, winter wheat or rye may be sown in the spring, and without the overwintering period (vernalization), little or no seed production occurs and a dense cover remains. Annual broadleaf weeds can be controlled by mowing and by the use of the herbicides listed in Table 3. Tillage prior to small-grain planting will help control established weeds.

Planting a small-grain/legume combination is another option for set-aside. Utilizing the small grain as a nurse or companion crop may help reduce weed pressure and alleviate the need for herbicides. If weeds become a problem, refer to Table 6 for more information in selecting the appropriate herbicide. In addition to those herbicides listed in Table 6, **Buctril** may also be used to control broadleaf weeds in seedling alfalfa-grass mixes on Conservation Reserve Program acres. Refer to current label rates and restrictions.

Sorghum-sudan grass can make a rapid, vigorous cover that also effectively suppresses many weeds. Although herbicides are rarely needed in sorghum-sudan grass stands, mowing and tillage may be difficult; and viable seed sometimes causes weed problems the next year.

Acreage Conservation Reserve land offers a unique opportunity for controlling problem weeds such as perennials and keeping other more common weeds in check. By managing ACR land this year, controlling weeds in future row crops will be less difficult and more profitable.

1990 Weed Management Guide

FOR COMMERCIAL VEGETABLE GROWERS

WEED MANAGEMENT requires a multifaceted approach, built upon an understanding of weeds and the crop. Weed management may involve nonchemical (organic) methods, chemical (herbicides) methods, or a combination of the two. The decision on which methods to use depends on environmental concerns, marketing opportunities, desired management intensity, labor availability, weed pressure, and the crop.

The first step in weed management is to identify the weeds and understand their life cycles. Consult identification guides, such as *Weeds of the North Central States* (NCR Research Publication No. 281, College of Agriculture, University of Illinois at Urbana-Champaign) for assistance. Weeds can be categorized by life cycles, and management strategies developed accordingly. Annual weeds complete their life cycles in one year and reproduce solely by seeds. Annuals can be divided into summer or winter annuals depending on when they grow. Primary tillage operations often control winter annuals before a crop is planted in the spring. The most common vegetable crop weeds (i.e., barnyardgrass, giant foxtail, common purslane, redroot pigweed, and common lambsquarters) are summer annuals. Mechanical and cultural weed management methods help in suppressing summer annuals. Perennial weeds live for more than two years and can reproduce by seed or vegetative structures (stolons, rhizomes, corms, bulbs, tubers, or roots). Because perennial weeds are impossible to manage in vegetable crops, it is usually better not to use a field with severe perennial weed problems.

This revision features three sections: nonchemical weed management strategies, chemical weed management strategies, and environmental and health hazards of herbicides. Many nonchemical weed management methods are commonsense farming practices. These practices are of increasing importance due to consumer concerns about pesticide residues, potential environmental contamination from pesticides, and unavailability of many older herbicides.

Nonchemical Weed Management Strategies

Weed management should start with nonchemical strategies that reduce problems caused by weeds. Their aim should be to manage the weed population so it is below a level which will cause a reduction in your economic return (economic threshold). In some instances, the cost of controlling weeds may be more than the economic return obtained from any yield increase. This situation occurs when a few weeds are present or the weeds germinate late in the season. In those instances, the best strategy may be to do nothing. In other situations weed populations and other considerations may require combining herbicides with nonchemical approaches.

Cultural Practices

You should aim to establish a vigorous crop that competes effectively with weeds. This starts with your *land selection*. A general rule is not to plant vegetables on land with a history of heavy weed infestation, especially perennial weeds. *Crop selection* can reduce the effects of weed competition. The crop selected should depend on the weed problems of the field. Plant the most competitive crops in the most weed-infested fields and the least competitive crops in the cleanest ones. Consider planting heavily infested fields as long-term set-aside acres or in nonrow crops such as alfalfa. Permanent cover should prevent buildup of annual weeds.

Crop rotation is another practice which can reduce weed problems. The characteristics of the crop, the methods used to grow it, and the herbicides used inadvertently allow certain weeds to escape control. Rotation also affects the weed management tools at your disposal. Rotating between crops will improve growth and the crop's competitiveness.

A number of different rotations can be used, but some general observations have been made. Legumes, onions, and squash are beneficial, while carrots, beets, and cabbage are detrimental as preceding crops. Also, related vegetables should not be grown in the same location in successive years. Table 1 lists related vegetable crops.

Wild proso millet is an example of a problem weed where rotation is important for management. Rotating from sweet corn to small grains, early-planted peas, or alfalfa almost completely eliminates wild proso millet. Alfalfa, early-planted peas, and small

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
Prepared by J.B. Masiunas (revised annually) CIRCULAR 907-90 (October 1989)

Table 1. Botanically Related Vegetables

Corn	Cucurbits	Crucifers	Legumes
Sweet Corn	Winter squash	Rutabaga	Soybeans
Dent Corn	Summer Squash	Kale	Peas
Onions	Pumpkin	Broccoli	Snap Bean
Onion	Muskmelon	Cauliflower	Lima Bean
Garlic	Watermelon	Cabbage	Dry Bean
Spinach	*Solanaceous*	Brussels Sprout	
Beets	Potato	Radish	
Chard	Tomato	Horseradish	
Spinach	Pepper		

grains establish before the soil is warm enough for wild proso millet to germinate. Rotating from sweet corn to broadleaf crops allows postemergence grass herbicides to be used to manage wild proso millet.

Once a crop is selected use *adaptive vigorous varieties* resistant to diseases. Disease-infested plants cannot effectively compete with weeds. Varieties suited for cultivation in Illinois are listed in *Vegetable Varieties for Commercial Growers* (Circular 1174, University of Illinois at Urbana-Champaign, Cooperative Extension Service).

Narrower row spacings and proper plant densities assure the crop rapidly closes canopy. A closed canopy shades out later emerging weeds and prevents weed seeds requiring light from germinating. Weeds seldom are a problem once canopy closure occurs. Proper row spacing and plant density also allow row cultivation.

Another cultural method to improve crop competitiveness is to use the *correct planting time.* Crops can be divided into warm- or cool-season plants depending on the optimum temperature for their growth. Planting date affects the time to emergence and early seedling vigor of the crop, which are important in determining crop competitiveness. Cool-season crops germinate at cooler soil temperatures and thus compete better against early emerging weeds than warm-season crops. Table 2 lists crops according to their adaptation to field temperatures. Time plantings so that temperatures are favorable for crop growth.

Adequate fertilization and appropriate insect and disease management are important in assuring a competitive crop. Adequate fertility assures rapid, uniform germination and good crop growth, which enhance the crop's competitive ability. For information on fertility, consult *Fertilizer Guide for Commercial Vegetable Growers* (Circular 1185, University of Illinois at Urbana-Champaign, Cooperative Extension Service). Disease management information is contained in *1990 Disease Management Guide for Commercial Vegetable Growers* (Circular 1184, University of Illinois at Urbana-Champaign, Cooperative Extension Service) and insect management information is in *1990 Insect Pest Management Guide: Commercial Vegetable Crops* (Circular 897, University of Illinois at Urbana-Champaign, Cooperative Extension Service). While poor insect and disease control reduce a crop's competitiveness, inadequate weed control can also cause insect and disease problems.

Table 2. Classification of Vegetable Crops According to Their Adaptation to Field Temperatures

Cool-Season		Warm-Season	
Hardy*	Semi-Hardy	Tender	Very Tender
Asparagus	Carrot	Snap Bean	Cucumber
Broccoli	Cauliflower	Sweet Corn	Eggplant
Cabbage	Chinese Cabbage	Tomato	Lima Bean
Horseradish	Lettuce		Muskmelon
Onion	Potato		Okra
Peas			Pepper
Spinach			Pumpkin
			Squash
			Watermelon

*Hardy crops are most tolerant of cool temperatures and frost, while very tender crops are most susceptible to frost and cool temperatures.

Mulching can be useful in managing weeds. Mulches can be classified as either organic (i.e., straw, leaves, paper, and compost) or plastic sheets. Because organic mulches are difficult to apply over large areas, they are best for small specialized areas. Organic mulches should be spread evenly at least 1-1/2 inch thick over the soil to prevent light penetration. Organic mulch materials must be free of weed seeds and other pest organisms and be heavy enough so they will not be easily displaced by wind or water. A major advantage of organic mulches is that they add organic matter to the soil.

Plastic mulches are easy to apply, control weeds within the row, conserve moisture, and increase soil temperature. Black plastic mulches are the most common. Plastic mulches are particularly effective in improving early-season crop growth of warm-season crops such as tomatoes, muskmelons, watermelons, or peppers. Plastic mulches used in combination with trickle irrigation improve water use efficiency.

The biggest disadvantage of plastic mulch is disposing of the plastic. Many landfills do not accept plastic mulches. Photodegradable plastic mulches have been developed, but their season-long persistence has been a problem. Photodegradable mulches also degrade into small pieces of plastic that contaminate the environment. Biodegradable plastic mulches are not yet widely available.

Mechanical Practices

Mechanical weed management relies on primary and secondary tillage implements such as the rotary hoe and the row cultivator. Mechanical weed management starts with seedbed preparation. Few no-till systems have been developed for vegetable crops. No-till suggestions are included in the section on herbicides.

Moldboard plowing is usually the first step in mechanically managing weeds. Moldboard plowing is particularly useful in controlling emerged annual weeds. *Rotary hoeing* is often an important second step in mechanically managing weeds in large-seeded vegetable crops (i.e., sweet corn, snap beans, lima beans, and peas). Rotary hoeing needs to be done after the weeds germinate but before they emerge. Large-seeded weeds, such as velvetleaf and shattercane, will not be controlled by rotary hoeing.

Once the crop has emerged or transplants are established, a *row cultivator* can be used to manage emerged weeds. Adjust the cultivator sweeps or teeth to dislodge or cover as many weed seedlings as possible. Seedling weeds can be killed by cultivating 1 to 2 inches deep. Best weed control is obtained using a row cultivator in relatively dry soils and throwing soil into the crop row to cover small weed seedlings. Avoid crop injury from poor cultivation, which will reduce crop yields.

In some vegetable crops, such as asparagus, *mowing* can be an effective weed management tool. Mowing can prevent the production of weed seeds and kill upright weeds, reducing competition. Mowing must be carefully timed to prevent the production of viable seed. Mowing may favor low-growing or biennial weeds by reducing competition from upright plants. Timely repeated mowing also helps deplete the food reserves of perennial weeds.

Mechanical control has a number of limitations that must be considered when designing weed management systems. Mechanical management relies on relatively dry weather, and a rainy period may eliminate mechanical management options and lead to severe weed competition. Relying entirely on mechanical practices to manage weeds is difficult on large acreages. Also, several weeds are extremely difficult to manage unless herbicides are combined with nonchemical approaches. Some of the problem weeds include wild proso millet in sweet corn, Canada thistle, hemp dogbane, field bindweed, quackgrass, and johnsongrass. Newly introduced problem weeds often show up in scattered patches along headlands and field borders. These are best controlled or eradicated with herbicides before large areas are infested.

Biological Practices

Currently no systems exist in the Midwest using insects or diseases to control weeds common to vegetable crops. Most biological management systems using diseases or insects to control problem weeds have centered on rangeland areas in the West. One biological system that has potential in the Midwest is the use of cover crops to suppress the development of weeds. These systems are still experimental, and problems have been encountered. The problems include the duration of weed control from cover crops and the spectrum of weeds controlled. Herbicides are often required to kill the cover crop and to manage any emerged weeds. Overall, cover crop systems tend to control small-seeded annual broadleaf weeds the best. The most promising cover crop system is winter rye. Winter rye is planted in the late summer or early fall; the rye is killed in the spring with Roundup or Poast; and the crop is no-till planted. The system is experimental and should be evaluated in small areas before extensive use.

Table 3 summarizes some of the nonchemical weed

Table 3. Summary of Nonchemical Weed Management Practices

Practice	Comments
Cultural	
1. Land selection	Avoid fields with history of weed problems.
2. Crop selection	Grow the most competitive crops in fields with history of weed problems.
3. Crop rotation	Rotate between vegetables and non-row crops such as alfalfa. Rotate between vegetables in different botanical categories.
4. Adapted crop varieties	Select crop varieties adapted for your area.
5. Proper row spacings and plant densities	Use row spacings and plant densities that assure rapid crop canopy closure.
6. Correct planting times	Plant crops when soil temperatures favor rapid germination and emergence. Do not plant warm-season crops too early in the season.
7. Appropriate fertility, disease and insect management	Vigorous, healthy crops are more competitive against weeds.
8. Mulch	Organic mulches are difficult to use over large acreages. Plastic mulches are useful to manage weeds within the row in warm-season crops. Consider disposal problems when using plastic mulches.
Mechanical	
1. Moldboard plowing	Can eliminate emerged annual weeds.
2. Rotary hoeing	Useful to manage small-seeded weeds in large-seeded crops such as sweet corn, snap beans, lima beans, and peas.
3. Row cultivator	Dislodge or cover as many weed seedlings as possible. Avoid damaging crop root systems.
4. Mowing	Mow weeds as soon as flowers appear so no viable weed seed is produced.
Biological	
1. Cover crops	Still experimental. Winter rye system is the most promising — most effective against small-seeded broadleaf weeds.
2. Insect or disease pests of weeds	No current systems use insects or diseases to manage weeds common to vegetables.

management practices. An integrated approach should be used which combines many different practices to manage weeds. This approach must be adaptive, aiming to prevent weed problems or cope with any that occur.

Chemical Weed Management Strategies

The University of Illinois and its agents assume no responsibility for results from the use of herbicides, whether or not they were used in accordance with suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Several herbicides are often labeled for a crop. Scouting your area to determine which weeds are present will allow you to select the herbicide that will give you the best control. Potential environmental hazards must be considered when selecting a herbicide. Herbicide labels contain information on these hazards. The last section of this publication also discusses potential environmental hazards.

All the herbicides labeled for a crop are not necessarily listed below. Also, because revisions may change some herbicide uses, always read and follow carefully the directions on a current herbicide label before using any product. If you are unfamiliar with a herbicide, conduct a small test under your environmental conditions and cultural practices before using the herbicide extensively.

Always Read and Understand the Herbicide Label before Use

Reading the herbicide label is a very profitable use of your time. Information on the label will direct you to the correct uses, application methods, rates, and potential environmental hazards. Following label directions will result in the best possible control with minimal crop injury and environmental degradation. The label contains restrictions on use and discusses environmental and soil conditions that affect crop injury, influence the effectiveness of weed control, and can cause nontarget site effects.

Do Not Use Any Herbicide Unless the Label States that It Is Cleared for Your Particular Use and Crop

Using a nonregistered pesticide can cause harmful residues in the vegetable crop, which can result in crop seizure and consumer injury. The label also states whether the herbicide is a restricted-use or general-use pesticide. Restricted-use pesticide labels contain a statement that the products are restricted, and that only licensed applicators can buy them and supervise their application.

The information in this circular is current as of the date of publication. Watch for notices of changes in the U.S. Environmental Protection Agency (EPA) registration of herbicides in the *Illinois Vegetable Farmer's Letter* or the *Insect, Weed, and Plant Disease Survey Bulletin.* Contact your county Extension adviser or Vegetable Crops Extension, University of Illinois, 1103 West Dorner Drive, Urbana, Illinois 61801, for subscription information.

Reduced Tillage Systems

Reduced tillage systems are a method to combat soil erosion. Roundup, Gramoxone Super, or Gramoxone Extra can be applied outside the normal growing season to control emerged weeds in reduced tillage systems. Weeds should be growing actively and the application must be made before the crop has emerged. If you are applying Roundup to control perennial weeds, it is recommended that Roundup be applied before disturbing the soil. Once Roundup has been applied, it must be allowed to translocate throughout the perennial weed for several days or incomplete control may result. Follow Roundup label directions carefully for the rates and timing of application. If perennial weeds are not a major problem, you can eliminate early flushes of weeds by applying Roundup, Gramoxone Super, or Gramoxone Extra to all weeds that emerge. Plant the crop with minimal working of the soil. Never apply Roundup, Gramoxone Super, or Gramoxone Extra to an emerged crop because severe crop injury or death will occur.

Roundup, Gramoxone Super, and Gramoxone Extra will control most annual broadleaf and grass weeds. Neither herbicide has any soil residual activity, so other weed control measures will be necessary during the growing season. Gramoxone Super and Gramoxone Extra will also suppress perennials by killing their shoots but should not be expected to control regrowth of perennial weeds from rhizomes or other underground storage organs. Roundup is better for controlling perennials, because it will kill shoots and translocate to destroy underground parts. Roundup will only suppress some particularly hard-to-control perennials such as bindweed, hemp dogbane, and milkweed. To obtain control of these perennials, applications of high rates or repeat applications of Roundup (within label guidelines) or mechanical removal may be necessary.

How to Use Herbicide Tables

Use Table 4 to determine the herbicides that are labeled for use in your crop. Once you have determined the herbicides available for your crop, use Table 5 to determine which of the labeled herbicides will provide control of the weeds you have present. If you are not certain of the herbicide name, both the common name and the trade names of all herbicides in this circular are listed in Table 6. These tables are not intended to replace careful reading of a current herbicide label. **ALWAYS READ THE LABEL BEFORE APPLYING ANY PESTICIDE.**

HERBICIDE RATES AND GUIDELINES FOR USE IN VEGETABLE CROPS

All herbicide rates given in Table 4 are in amount of product per broadcast acre. Adjust amounts accordingly for banded applications. Preemergence applications should be made before weeds emerge or after removing any weeds present. Postemergence applications should be made after weeds have emerged. Stale seedbed treatments should only be made if weeds have emerged but no crop plants are present.

Re-registration of older herbicides has affected the availability of a number of products. For example, neither Enide nor Amiben will be re-registered; thus, their future availability is questionable and they have been removed from this revision. Some of the older herbicides not listed in this circular may be available and old stocks can still be used.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops

Herbicide	Rate of product per broadcast acre	Remarks
	ASPARAGUS	
Preemergence		
Devrinol (napropamide)	4-6 lb of 50WP	Rainfall or irrigation is necessary for activity. Established beds only.
Karmex, others (diuron)	2-4 lb of 80WP	Do not apply to young plants during the first year. Two applications per year can be made. See label restrictions.
Lexone or Sencor (metribuzin)	1.3-2.5 lb of 75DF	Established beds only.
Princep, others (simazine)	2-4 lb of 80WP	Established beds only.
Sinbar (terbacil)	1.5-3 lb of 80WP	With direct seeded asparagus, spray activated carbon over rows. High organic soils inactivate Sinbar.
Treflan (trifluralin)	1-1.5 pt of 4EC, or 2-4 pt of MTF	See label for incorporation instructions. Established beds only.
Postemergence		
2,4-D amine	See label	Apply to actively growing weeds.
Fusilade 2000 (fluazifop-butyl)	16-48 fl oz of 1EC	NONBEARING ASPARAGUS ONLY. Use crop oil concentrate or a nonionic surfactant. See label for amount.
Poast (sethoxydim)	1.5-2 pt of 1.5EC	NONBEARING ASPARAGUS ONLY. Use crop oil concentrate. See label for amount.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems. Apply at least 1 week before spears emerge, or delay until after harvest.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
	CARROTS	
Preemergence		
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Fusilade (fluazifop-butyl)	1-1.5 pt of 1EC	Use crop oil concentrate or nonionic surfactant. Up to 2 applications can be made per year.
Linex or Lorax (linuron)	1.5-3 lb of 50DF	Carrots must be at least 3 inches tall. Apply before grasses are 2 inches tall.
Sencor (metribuzin)	0.33 lb of 75DF or 0.5 pt of 4L	See label warnings. Carrots must have at least 5-6 leaves. Weeds must be small.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	COLE CROPS (Broccoli, Brussels Sprout, Cabbage, Cauliflower, and Turnip)	
Preemergence		
Dacthal (DCPA)	8-11 lb of 75WP	Not effective on high organic soils. Can be sprayed directly over transplants.
Devrinol (napropamide)	2-4 lb of 50WP	Can apply to transplants or direct-seeded plants. Should incorporate shallowly.
Goal (oxyfluorfen)	1.25 to 2.5 pt of 1.6EC	Apply to soil after final tillage but before transplanting. May cause foliar injury. Do not apply to brussels sprout.
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Direct-seeded cole crops exhibit marginal tolerance to Treflan. Stunting can occur under stress. Must be incorporated.
Postemergence		
Poast (sethoxydim)	1.5-2 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	CORN (Sweet and Popcorn)	
Preemergence		
AAtrex, others (atrazine)	2-4 lb of 80WP, or 4-6 pt of 4L, or 2.2-3.3 lb of Nine-O	Land treated with atrazine should not be planted with any vegetable the following year or injury may occur.
Bladex (cyanazine)	1.5-6.0 lb of 80WP, or 1.3-5.3 lb of 90DF, or 1.25-4.75 qt of 4L	
Dual (metolachlor)	1.5-3 pt of 8EC, or 6-12 lb of 25G.	Can be incorporated or applied before emergence.
Eradicane Extra (EPTC + safener + extender)	4-8 pt of 6.7EC	Will suppress wild proso millet. Must be incorporated. Contains an extender that may lengthen the period of control.
Genate Plus or Sutan + (butylate + safener)	4.75-7.33 pt of 6.7EC	Especially useful on sandy soils. Must be incorporated.
Lasso (alachlor)	2-4 qt of 4EC	

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
Princep, others (simazine)	3.75-5 lb of 80WP, or 6-8 pt of 4L	Do not plant vegetables the year following application. Do not graze treated area.
Prowl (pendimethalin)	1.5-4 pt of 4EC	Do not incorporate. For use on processing varieties. Do not apply prior to planting.
Postemergence		
AAtrex, others (atrazine)	4-6 pt of 4L, or 2.5-3.75 lb of 80WP, or 2.2-3.3 lb of Nine-O	Can be applied with crop oils. Preemergence applications preferred. See label precautions.
Basagran (bentazon)	1.5-2 pt of 4S	Apply when weeds are small. Consult label for specific directions.
2,4-D amine	See label	Apply to actively growing weeds, preferably before corn is 6 inches tall. See label restrictions. Sweet corn injury may occur.
Stale Seedbed		
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
CUCURBITS (Cucumber, Muskmelon, and Watermelon)		
Preemergence		
Alanap (naptalam)	6-8 qt of 2L	A second application can be made prior to vining. Normally tank mixed with Prefar.
Curbit	3-4.5 pt of 3EC	Read label carefully before using. Avoid using on cool wet soils. Requires signing a waiver before using.
Dacthal (DCPA)	6-14 lb of 75WP	Apply when the crop is at the 4-5 true leaf stage. For use on direct-seeded cucurbits only.
Prefar (bensulide)	5-6 qt of 4EC	Incorporate or irrigate in. Can tank mix with Alanap. Do not plant other than label-specified crops for 18 months after application.
Postemergence		
Poast (sethoxydim)	1.5-2 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
DRY BEANS (White, Navy, Kidney, Pinto, Lima, and Adzuki)		
Preemergence		
Dacthal (DCPA)	8-11 lb of 75WP	
Dual (metolachlor)	1.5-3 pt of 8EC	
Eptam or Genep (EPTC)	2.5-3.5 pt of 7EC	Do not use on adzuki beans, cowpeas, lima beans, or other flat pod beans. Incorporate immediately.
Prowl (pendimethalin)	1-1.5 qt of 4EC	Must be incorporated.
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Basagran (bentazon)	1.5-2 pt of 4S	Apply when weeds are small. Beans are tolerant after the first trifoliate leaf has expanded.
Stale Seedbed		
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
	EGGPLANT	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Apply 4-6 weeks after transplanting or when direct-seeded plants are 4-6 inches tall. Cultivate if weeds have emerged before applying.
Devrinol (napropamide)	2-4 lb of 50WP	Transplanted eggplant only.
Postemergence		
Poast (sethoxydim)	1-1.5 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
	GREENS (Chicory, Collard, Kale, Mustard, Spinach, Turnip Greens)	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	For use on collards, kale, mustard, and turnip greens. Not effective on high organic matter soils.
Treflan (trifluralin)	1-1.5 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Poast (sethoxydim)	1-1.5 pt of 1.5EC	Spinach or mustard greens only. Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	Collards only. See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	HORSERADISH	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Apply uniformly to soil at planting time.
Stale Seedbed		
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	LETTUCE	
Preemergence		
Balan (benefin)	3-4 qt of 1.5EC	Direct-seeded lettuce only. Must be incorporated.
Kerb (pronamide)	2-4 lb of 50WP	Moisture is necessary to activate. Label rates vary depending on variety.
Prefar (bensulide)	5-6 qt of 4EC	Can be applied to head and leaf lettuce. Must be incorporated.
Postemergence		
Poast (sethoxydim)	1-1.5 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
	OKRA	
Preemergence		
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Must be incorporated immediately after application.
Stale Seedbed		
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	ONION	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Can be applied at planting or at layby. Emerged weeds will not be controlled.
Postemergence		
Buctril (bromoxynil)	0.5-0.75 pt of 4ME	Apply when onions have 2-5 true leaves. Sensitivity of onions is affected by variety and environment.
Goal (oxyfluorfen)	0.6 pt of 2EC	Do not apply until onions have 2 true leaves. Best control achieved when weeds are in the 2-4 leaf stage.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	PEAS	
Preemergence		
Dual (metolachlor)	1.5-3 pt of 8EC	Can be incorporated. See label for restrictions.
Command (clomazone)	1 pt of 4EC	Must be incorporated.
Treflan (trifluralin)	1-1.5 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Basagran (bentazon)	1.5-2 qt of 4S	Apply when weeds are small. Pea injury can occur. See label precautions.
Thistrol (MCPB)	2-6 pt of 2EC	Apply when peas have developed 6-12 nodes and weeds are less than 3 inches tall.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	PEPPER	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Apply 4-6 weeks after transplanting or when direct-seeded plants are 4-6 inches tall.
Devrinol (napropamide)	2-4 lb of 50WP	Can be applied to direct-seeded plants or transplants. Incorporate.
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Incorporate. Apply to transplants only.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
Postemergence		
Poast (sethoxydim)	1.5-2 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
	POTATO	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Apply at planting, drag off, or at layby.
Dual (metolachlor)	1.5-3 pt of 8EC, or 6-12 lb of 25G	Apply preemerge, incorporated, or at layby. Do not use on muck soils.
Eptam or Genep (EPTC)	3.5-7 pt of 7EC	Incorporate immediately after applying. The variety Superior is sensitive.
Lexone or Sencor (metribuzin)	0.6-1.33 lb of 75DF	Make a single application prior to emergence.
Linex or Lorox (linuron)	1.5-2.5 pt of 4L, or 1-4 lb of 50WP or 50DF	Apply after planting but before potato emergence. Plant "seed" 2 inches deep.
Prowl (pendimethalin)	1.5-3 pt of 4EC	Incorporate lightly. Do not use on muck soils.
Treflan (trifluralin)	1-2 pt or 4EC or MTF	Apply after planting and incorporate uniformly.
Postemergence		
Lexone or Sencor (metribuzin)	0.5-1 pt of 4L, or 0.3-0.67 lb of 75DF	Do not use on smooth-skinned white or red-skinned potatoes. Apply only if 3 successive days of sun have occurred prior to application. Apply before weeds are 1 inch tall.
Poast (sethoxydim)	1-1.5 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	PUMPKIN AND SQUASH	
Preemergence		
Command (clomazone)	2 pt of 4EC	Pumpkins only. Requires incorporation. May cause some temporary bleaching of pumpkin plants.
Dacthal (DCPA)	6-14 lb of 75WP	Not effective on soils with greater than 5% organic matter. Use on summer and winter squash only. Apply when plants are well established and have 4-5 leaves.
Prefar (bensulide)	5-6 qt of 4EC	Incorporate or irrigate in. See label restrictions.
Postemergence		
Poast (sethoxydim)	1-1.5 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
	SNAP BEANS OR GREEN BEANS	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Not effective on soils with more than 5% organic matter. Do not feed treated plants to livestock.
Dual (metolachlor)	1.5-3 pt of 8EC	
Eptam or Genep (EPTC)	3.5 pt of 7EC	Do not use on flat-podded beans. Must be incorporated.
Treflan (trifluralin)	1-1.5 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Basagran (bentazon)	1.5-2 pt of 4S	Apply when weeds are small. Beans are tolerant after the first trifoliate has fully expanded. Some injury to beans may occur.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	TABLE BEET	
Preemergence		
Pyramin (pyrazon)	3-3.5 qt of 4.2FL	Rainfall or irrigation is needed for activation.
Ro-Neet (cycloate)	2-2.7 qt of 6EC	Must be incorporated. Use on mineral soils only.
Postemergence		
Pyramin (pyrazon)	3.5 qt of 4.2FL	Timing is very important. Treat when beets have 2 expanded leaves and weeds have 2-4 leaves.
Stale Seedbed		
Roundup (glyphosate)	1.5-3 qt	See discussion of reduced tillage systems.
	TOMATO	
Preemergence		
Dacthal (DCPA)	6-14 lb of 75WP	Apply when direct-seeded plants are established and 4-6 inches tall or when transplanted plants have been established for 4-6 weeks.
Devrinol (napropamide)	2-4 lb of 50WP	Must be incorporated.
Lexone or Sencor (metribuzin)	0.5-1 pt of 4L, or 0.33-0.66 lb of 75DF	Apply to transplanted tomatoes only. May be incorporated.
Prefar (bensulide)	4-5 qt of 4EC	Incorporate or irrigate in. Do not plant other than specified crops for 18 months after treatment.
Tillam (pebulate)	2.66-4 qt of 6EC	Do not use Tillam with row covers.
Treflan (trifluralin)	1-2 pt of 4EC or MTF	Must be incorporated. For direct-seeded plants apply at blocking or thinning as a directed spray between rows.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (continued)

Herbicide	Rate of product per broadcast acre	Remarks
Postemergence		
Lexone or Sencor (metribuzin)	0.5-0.75 pt of 4L, or 0.33-0.67 lb of 75DF	Plants must be established; see label. Apply only if 3 successive days of sun have occurred prior to application.
Poast (sethoxydim)	1.5-2 pt of 1.5EC	Use crop oil concentrate.
Stale Seedbed		
Gramoxone (paraquat)	1 qt of Super or 2-3 pt of Extra	See discussion of reduced tillage systems.

Table 5. Weed Susceptibility to Herbicides Labeled for Use in Vegetable Crops

Herbicide	Weeds controlled	
	Grasses	Broadleaves
AAtrex, others (atrazine)	barnyardgrass, foxtail, crabgrass, witchgrass	cocklebur, jimsonweed, lambsquarters, mustard, annual morningglory, nightshade, pigweed, purslane, ragweed, velvetleaf
Alanap (naptalam)		carpetweed, chickweed, cocklebur, hairy galinsoga, lambsquarters, purslane, ragweed
Balan (benefin)	annual bluegrass, barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, seedling johnsongrass	carpetweed, chickweed, knotweed, lambsquarters, pigweed, purslane
Basagran (bentazon)		Canada thistle, purslane, lambsquarters, ragweed, galinsoga, jimsonweed, smartweed, velvetleaf, wild mustard, cocklebur
Bladex (cyanazine)	annual bluegrass, barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, witchgrass	carpetweed, cocklebur, chickweed, purslane, morningglory, jimsonweed, lambsquarters, nightshade, pigweed, ragweed, velvetleaf, wild mustard
Buctril (bromoxynil)		mustard, cocklebur, pennycress, jimsonweed, annual morningglory, nightshade, lambsquarters, smartweed, pigweed
Command (clomazone)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, seedling johnsongrass	purslane, ragweed, jimsonweed, lambsquarters, smartweed, velvetleaf
Curbit (ethalfluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, fall panicum, seedling johnsongrass, shattercane, witchgrass	wild buckwheat, carpetweed, chickweed, lambsquarters, pigweed, nightshade, purslane
2,4-D amine		carpetweed, dandelion, dock, galinsoga, pigweed, jimsonweed, lambsquarters, morningglory, plantain, ragweed, smartweed, thistle, wild mustard
Dacthal (DCPA)	crabgrass, foxtail, barnyardgrass, goosegrass, annual bluegrass, seedling johnsongrass	carpetweed, lambsquarters, common chickweed, purslane
Devrinol (napropamide)	barnyardgrass, weedy brome, crabgrass, foxtail, goosegrass, seedling johnsongrass	chickweed, purslane, common groundsel, prostrate knotweed, lambsquarters, pigweed, prickly lettuce
Dual (metolachlor)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, witchgrass, yellow nutsedge	nightshade, carpetweed, galinsoga, pigweed
Eptam or Genep (EPTC)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, shattercane, witchgrass	annual morningglory, carpetweed, chickweed, lambsquarters, nightshade, purslane
Eradicane Extra (EPTC + safener + extender)	annual bluegrass, crabgrass, barnyardgrass, goosegrass, seedling johnsongrass, volunteer small grains, foxtail	annual morningglory, nightshade, carpetweed, lambsquarters, purslane, pigweed, velvetleaf

Table 5. Weed Susceptibility to Herbicides Labeled for Use in Vegetable Crops (continued)

Herbicide	Weeds controlled: Grasses	Weeds controlled: Broadleaves
Fusilade 2000 (fluazifop-butyl)	bermudagrass, goosegrass, johnsongrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Genate Plus or Sutan+ (butylate + safener)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, shattercane, seedling johnsongrass	
Goal (oxyfluorfen)		eveningprimrose, pigweed, common groundsel, purslane, black nightshade, shepherdspurse
Gramoxone Super or Extra (paraquat)	Most annual grasses and broadleaves.	See discussion of reduced tillage systems.
Karmex, others (diuron)	barnyardgrass, crabgrass, annual bluegrass, foxtail	pigweed, purslane, ragweed, chickweed, mustard, pennycress, velvetleaf
Kerb (pronamide)	barnyardgrass, brome, annual bluegrass, panicum, foxtail, goosegrass, volunteer small grains	carpetweed, chickweed, henbit, knotweed, purslane, lambsquarters, nightshade, morningglory
Lasso, Stall (alachlor)	barnyardgrass, crabgrass, foxtail, goosegrass, fall panicum, witchgrass	carpetweed, pigweed, galinsoga, nightshade, purslane
Lexone or Sencor (metribuzin)	downy brome, crabgrass, foxtail, seedling johnsongrass	pigweed, purslane, ragweed, chickweed, jimsonweed, lambsquarters, pepperweed, shepherdspurse, smartweed, prickly sida
Linex or Lorox (linuron)	barnyardgrass, crabgrass, fall panicum, goosegrass	annual morningglory, carpetweed, groundsel, lambsquarters, mustard, cocklebur, pigweed, prickly sida, purslane, smartweed, velvetleaf
Poast (sethoxydim)	bermudagrass, goosegrass, johnsongrass, quackgrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Prefar (bensulide)	crabgrass, foxtail, fall panicum, goosegrass	
Princep, others (simazine)	annual bluegrass, crabgrass, foxtail, goosegrass, fall panicum, witchgrass	carpetweed, galinsoga, nightshade, pigweed, purslane, annual morningglory, mustard, lambsquarters, groundsel, pepperweed, ragweed, smartweed
Prowl (pendimethalin)	barnyardgrass, crabgrass, fall panicum, foxtail	carpetweed, lambsquarters, pigweed, purslane
Pyramin (pyrazon)		lambsquarters, pigweed, ragweed, shepherdspurse, purslane, nightshade, mustard, henbit, smartweed
Ro-Neet (cycloate)	annual bluegrass, crabgrass, volunteer barley, foxtail, barnyardgrass	nightshade, henbit, lambsquarters, purslane, redroot pigweed, shepherdspurse
Roundup (glyphosate)	Most annual and perennial grasses and broadleaves. See discussion of reduced tillage systems.	
Sinbar (terbacil)	crabgrass, foxtail, seedling johnsongrass, barnyardgrass, annual bluegrass	chickweed, lambsquarters, wild mustard, pepperweed, shepherdspurse, dandelion, knotweed, pigweed, purslane, plantain, ragweed, henbit, jimsonweed
Thistrol (MCPB)		Canada thistle, lambsquarters, pigweed, smartweed, sowthistle, annual morningglory
Tillam (pebulate)	barnyardgrass, crabgrass, foxtail, goosegrass	lambsquarters, pigweed, purslane, shepherdspurse
Treflan (trifluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, seedling johnsongrass, goosegrass	carpetweed, chickweed, knotweed, lambsquarters, pigweed, purslane

Table 6. Common and Corresponding Trade Names that Appear in This Circular

Common name	Trade name
alachlor	Lasso
atrazine	AAtrex, others
benefin	Balan
bensulide	Prefar
bentazon	Basagran
bromoxynil	Buctril
butylate + safener	Genate Plus, Sutan +
clomazone	Command
cyanazine	Bladex
cycloate	Ro-Neet
2,4-D amine	several names
DCPA	Dacthal
diuron	Karmex, others
EPTC	Eptam, Genep
EPTC + safener + extender	Eradicane Extra
ethalfluralin	Curbit
fluazifop-butyl	Fusilade
glyphosate	Roundup
linuron	Linex, Lorox
MCPB	Thistrol
metolachlor	Dual
metribuzin	Lexone, Sencor
napropamide	Devrinol
naptalam	Alanap
oxyfluorfen	Goal
paraquat	Gramoxone Super or Extra
pebulate	Tillam
pendimethalin	Prowl
pronamide	Kerb
pyrazon	Pyramin
sethoxydim	Poast
simazine	Princep, others
terbacil	Sinbar
trifluralin	Treflan

Environmental and Health Hazards of Herbicides

Nontargeted effects can occur from the use of herbicides. With the increased attention directed toward nontargeted effects of pesticides, it is very important that you educate yourself about these effects and consider them when designing weed management systems. The following section contains discussions on some of the potential environmental and health hazards of herbicides. This is only an overview. More detailed information is contained in the herbicide label, the *1990 Illinois Pest Control Handbook* (University of Illinois at Urbana-Champaign, Cooperative Extension Service), and 1987, 1988, and 1989 *Proceedings of the Illinois Fruit, Vegetable, and Irrigation Convention* (University of Illinois at Urbana-Champaign, Department of Horticulture).

Environmental Hazards

Adverse environmental effects from herbicides can have long-term consequences which are difficult to correct and must be avoided. Some environmental hazards, such as herbicide drift and carryover, will mainly affect your operation, while other hazards such as water quality, affect all the residents of Illinois. The following section discusses some of the potential hazards and methods to avoid them.

Herbicide Carryover. Herbicide carryover from persistent herbicides has been a particular problem to growers of vegetable crops. Persistence is dependent on herbicide characteristics (i.e., method of degradation, water solubility, and rate of application) and site characteristics (i.e., soil type, rainfall, and temperature). Because correction of carryover problems once they occur is virtually impossible, carryover must be avoided. The most important method to avoid herbicide carryover is to follow label rotation restrictions. Label restrictions should be considered as minimum guidelines. Table 7 summarizes some of the label restrictions. Always refer to the label for specific information. If differences between the table and herbicide label occur, always follow label information. Further information on avoiding vegetable crop injury from herbicide carryover is also contained in recent editions of the *Proceedings of the Illinois Fruit, Vegetable, and Irrigation Convention* (University of Illinois at Urbana-Champaign).

Herbicide drift. Another frequent hazard to vegetable growers is crop injury from herbicide drift. Certain herbicides, if not used correctly, can cause injury to nontarget plants. Herbicides such as Command, dicamba, and 2,4-D can drift up to a mile and cause serious damage to grapes, tomatoes, peppers, other vegetables, fruit trees, and ornamental plants. Before spraying Command, dicamba, or 2,4-D, survey the area for desirable plants. Spray only on calm days and use drift inhibitors when appropriate. Minimize drift by applying herbicides with nozzles that produce large droplets. Use an amine formulation of 2,4-D to reduce vapor drift. Spray Command, dicamba, and 2,4-D when the temperature is expected to be lower than 80-85°F for several days after treatment. Avoid applying Command to wet soils and incorporate Command soon after application.

Spray tank residuals. Dicamba or 2,4-D residues in spray tanks can also injure susceptible vegetable crops. Carefully follow label directions for cleaning spray equipment after using dicamba or 2,4-D. If possible, do not use the same spray equipment to apply 2,4-D or dicamba that you use to apply other pesticides.

Herbicide resistance. There are now more than 50 documented reports worldwide of weeds developing resistance to herbicides. Herbicide resistance tends to occur when a persistent herbicide is used year after year in the same field. Thus, continued use of the same herbicide on a perennial crop such as asparagus should be avoided. Many of the resistant problems have occurred with triazine herbicides such

Table 7. Label Restrictions (in Months) on Rotating to Vegetable Crops

AT = herbicide labeled for the crop or no rotation restriction exists, NY = the crop can be planted the year after application, NNY = the crop cannot be planted the following year, and FB = a field bioassay required before planting the crop.

	Crop						
Herbicide	Tomato	Pea	Snap Beans	Sweet Corn	Pumpkin	Melon	Cole Crops
Soybean Herbicides							
Canopy	FB[1]	FB	FB	18	FB	FB	FB
Classic	FB	FB	FB	FB	FB	FB	FB
Command	NNY	AT	9	9	AT	9	NNY
Commence	NNY	9	9	9	9	9	NNY
Dual	18	AT	AT	AT	18	18	18
Lexone or Sencor	4-10	4-10	12	12	12	12	12
Lorox	NNY	NNY	NNY	4	NNY	NNY	NNY
Lorox Plus	FB	FB	FB	FB	FB	FB	FB
Preview	FB	FB	FB	FB	FB	FB	FB
Prowl	NY	NY	NY	AT[2]	NY	NY	NY
Pursuit	18	9.5	9.5	18	18	18	18
Reflex	18	18	18	10	18	18	18
Salute	4	8	12	4	12	12	12
Scepter	18	18	11	18	18	18	18
Squadron	18	18	11	18	18	18	18
Tri-Scept	18	18	11	18	18	18	18
Tackle or Blazer	8	8	8	8	8	8	8
Tornado	18	18	18	10	18	18	18
Treflan	AT[3]	AT	AT	5	5	5	AT
Turbo	12	8	8	12	8	12	12
Corn Herbicides							
AAtrex and others	NNY	NNY	NNY	AT	NNY	NNY	NNY
Bicep	18	18	18	AT	18	18	18
Bladex	NY	NY	NY	AT	NY	NY	NY
Conquest	18	18	18	AT	18	18	18
Lariat	NNY	NNY	NNY	AT	NNY	NNY	NNY
Princep	NNY	NNY	NNY	AT	NNY	NNY	NNY
Prozine	NNY	NNY	NNY	AT	NNY	NNY	NNY
Sutazine	18	18	18	AT	18	18	18

[1] The rotation restrictions are in months after application.
[2] Sweet corn for processing only.
[3] Transplanted tomatoes only.

as simazine and atrazine. The labels of those herbicides contain information about avoiding resistance problems.

Approaches to avoid herbicide resistance combine herbicides and mechanical (cultivation) and cultural (crop rotation) weed management practices. Rotate between or use tank mixes of herbicides with different mechanisms of killing the plant. For example, in asparagus rotate between Princep and Treflan. Use tillage to control weeds that escaped from herbicide applications. Especially important in minimizing any weed resistance that does occur is to scout your fields, paying special attention to any patches of a weed normally controlled by the herbicide.

Water quality. Residues of some herbicides such as atrazine, metolachlor, alachlor, cyanazine, and metribuzin have been found in surface and/or groundwater. The levels detected have normally been low, but contamination of water resources is a growing concern. For example, groundwater contamination from pesticides and nitrates is a particular concern in areas of the state with sandy soils and shallow groundwater.

Factors determining the potential for groundwater and surface water contamination include herbicide solubility in water, rate of degradation, volatility, and tendency for the herbicide to attach to soil particles or organic matter. Herbicides which have high water solubility and long persistence are a particular concern.

Site characteristics (soil type, soil depth, water table depth, slope, and weather) also can lead to contamination of water resources from herbicides. You should be aware of the potential problem of herbicide contamination and take all possible steps to avoid contamination of surface and subsurface water resources.

Disposing of herbicides and containers. *Surplus herbicides.* If possible use surplus herbicide mixtures by applying them to labeled crops that have the same weed problems. Never drain surplus pesticides in any location where they can contaminate ground or surface water supplies. Avoid creating surplus tank mixes by accurately measuring the treatment area and mixing the correct amount of pesticide. If a large amount of surplus pesticide is generated, contact the Illinois EPA Division of Land Pollution Control for instructions about disposal.

Pesticide containers. All empty containers, regardless of their type, should be rinsed three times before disposal. Rinse-water should be dumped into the tank. Triple-rinsed containers should be punctured or broken to facilitate drainage and to prevent reuse for any purpose. Containers should then be disposed of according to label directions and local regulations, with regard for the protection of water resources.

Health Hazards

Health hazards from exposure to pesticides can be divided into acute or chronic effects according to the duration and amount of exposure.

Acute effects. Acute effects or poisoning occur soon after exposure to large amounts of a pesticide. These types of effects are dangerous to you, your family, and your workers. The potential for human or animal poisoning from pesticides can be reduced by carefully storing and handling pesticides. Keep pesticides in a separate area, room, or building used only for storage purposes. The storage area should be dry and ventilated. Keep all entrances to the area locked at all times to protect children, other people, and animals. **CAUTION:** Do not store herbicides together with insecticides. Remove only the pesticide that will be used in one day, and after use return the pesticide to the storage area. **FOLLOW LABEL DIRECTIONS WHEN HANDLING PESTICIDES.** Pay particular attention to sections on protective clothing requirements and any field reentry limitations.

Herbicide residues in vegetables. The issue of pesticide residues in vegetables is currently receiving intense public attention. Many of the herbicides used in vegetable crops are older products and were registered before current toxological and environmental standards were established by the EPA. Congress has required the EPA to re-register these older products to bring the data up to current toxological and environmental standards. This re-registration has caused some companies to remove products from the market.

Data exists that some herbicides (and other pesticides) can potentially cause adverse health effects, such as cancer from chronic (long-term) exposure. There is controversy about the reliability and importance of this data. Groups that are particularly concerned about pesticide residues in vegetables include the National Resource Defense Council; National Coalition Against Misuse of Pesticides; and Americans for Safe Food. Because customers will question you, it is recommended that you stay up-to-date on this issue. The above groups have information reflecting their views. Information is available reflecting food industry views from such groups as The Alliance for Food and Fiber, Food Marketing Institute, and Center for Produce Quality. Recent editions of the *Proceedings of Illinois Fruit, Vegetable, and Irrigation Convention* also have articles on pesticide residues in vegetables.

1990 Herbicides for Commercial Tree Fruits

D. Meador and C. Doll

The suggestions in this publication comply with the regulations of the U.S. Department of Agriculture and the Environmental Protection Agency in effect at the time this publication was assembled. Since such regulations are subject to change, consult the most recent product label for use restrictions. *Do not use any herbicide unless the label states that it may be used on the crop to be treated.*

This guide is provided for your information. The University of Illinois and its agents assume no responsibility for results from using herbicies, whether or not they are used according to suggestions, recommendations, or directions of the manufacturer or any governmental agency.

CAUTION

Rates are for full coverage per acre. For spot or band treatments, reduce rates in proportion to the area actually treated.

Some products are not registered for use on sandy soils; others call for reduced rates on sandy soils. See labels.

Crop	Weeds Controlled	Treatment (overall basis) and comments
Apples, pears, cherries, peaches plums (prunes) bearing and nonbearing	Annual broadleaf and grass weeds	Casoron or Norosac granular (4%) at 150 lb per acre. Apply under trees in winter or early spring. For best results material should be lightly incorporated. Regrowth usually occurs in later summer. Avoid overdosage on young trees.
		Surflan (75%) at 2 2/3 lb to 5 1/3 lb per acre. Apply under trees in spring prior to weed emergence; use low rate for short-term control and high rate for long-term control. Allow soil to settle around young plants prior to treatment.

Crop	Weeds Controlled	Treatment (overall basis) and comments
Apples, pears cherries, peaches, plums (prunes) *continued*		Devrinol (50%) at 4 lb on sandy or light soils, 8 lb on heavy or dark-colored soils, in 20 to 100 gal of water per acre. Apply under trees in spring on weed-free soil or supplement with a postemergence herbicide. If no rainfall occurs within 48 hours after treatment, irrigate to incorporate.
		Solicam (80%) at 2 1/2 lb on light-colored soils, 5 lb on heavy or dark-colored soils, in 20 to 100 gal of water per acre. Apply to soil surface from fall to early spring before weeds emerge. Peaches must be established at least 6 months. Pears and plums must be established at least 12 months. Do not use on coarse textured soils such as sand, loamy sand, or gravelly sand. Avoid spray contact with fruit or foliage.
		Karmex (80%) or Princep (80%) at 2 1/2 lb on sandy or light-colored soils, 4 lbs on heavy or dark-colored soils, in 100 gal of water per acre. Apply under trees in spring. Use on weed-free areas, or supplement with a post-emergence herbicide. *Trees must be established at least 1 year.*
	Most annual broadleaf and grass weeds. Perennial weeds, top growth control only.	Gramoxone Super (paraquat-1.5 lb/gal) at 1 1/3 to 2 2/3 qt in 100 gal of water per acre. Apply as directed spray when weeds are growing rapidly and before they reach maturity. Repeat applications will be necessary to give sustained control. Use low pressure to produce a coarse spray. Add wetting agent to spray solution at 0.25% by volume for best results. *Caution: do not allow spray to contact leaves, fruit, or limbs of trees. Handle concentrates carefully.*

Crop	Weeds Controlled	Treatment (overall basis) and comments
All above except peaches	Most annual and certain perennial broadleaf and grass weeds.	Roundup at 1 to 2 qt in 10 to 40 gal of water per acre. Apply when weeds are in bud stage and growing actively. Application too early is not as effective in killing perennial weeds. *Caution: do not allow spray to contact any part of the tree since severe damage may result. Do not apply within 14 days of harvest.*
Apples, pears apricots, peaches and plums	Annual and perennial grass weeds.	Dowpon M (85%) at 10 lb in 100 gal of water per acre. Apply under trees when grass is 4 to 6 inches high in spring. *Do not use on trees younger than 4 years.* Do not apply within 30 days of harvest.
Apples and peaches	Most annual broadleaf and grass weeds.	Sinbar (80%) at 2 lb on light-colored soils, 4 lb on heavy or dark-colored soils in about 100 gal water per acre. Apply under trees once in spring. *Trees must be established 3 years or more.* Do not replant areas to crops within 2 years of last application. Use on weed-free soil or supplement with postemergence material. Do not use on extremely sandy soils.
Apples and pears	Many annual broadleaf and certain perennial broadleaf weeds.	Dacamine 4D at 1 to 2 qt in 100 gal of water per acre. Apply as directed spray when weeds are in prebud to early bud stage. *Caution: do not allow spray to contact leaves, fruit, or limbs of trees.* Useful to control broadleaf perennial weeds that escape earlier treatments. Use coarse spray to avoid drive.
Nonbearing fruit trees	Most annual and perennial grasses.	Poast 1.5E at 1 to 2 pt plus crop oil concentrate at 1 qt in 25 gal of water per acre; or Fusilade plus crop oil concentrate at 1 qt in 25 gal of water per acre. Apply as a directed spray when grass is actively growing. *Do not apply to trees that will be harvested within 1 year after application.*

CAUTIONS

If you are applying herbicides for the first time or are trying a new herbicide, learn on a small area.

Avoid spray drifts. Use low pressure (30 to 60 pounds per square inch) with nozzles close to the ground. Spray when wind velocity is low.

Calibrate equipment to apply the correct amount of material per acre. Excessive amounts may cause damage to fruit plants. Lesser amounts may not give control. Uniform application is essential.

Clean sprayers after applying herbicides. Use detergent and water (2 cups in 25 gallons) or ammonia and water (1 quart in 25 gallons) to clean out wettable-powder sprays. Emulsifiable liquids should first be washed out with kerosene, then with detergent and water or ammonia and water. Do not allow drain solutions to run into streams or other water sources.

For herbicide suppestions in home fruit plantings, see Circular 1144, *Controlling Weeds in Home Fruit Plantings*.

1990 Herbicides for Commercial Small Fruit Crops

D. Meador, C. Doll, and J. Courter

The suggestions in this publication comply with the regulations of the U.S. Department of Agriculture and the Environmental Protection Agency in effect at the time this publication was assembled. Since such regulations are subject to change, consult the most recent product label for use restrictions. *Do not use any herbicide unless the label states that it may be used on the crop to be treated.*

This guide is provided for your information. The University of Illinois and its agents assume no responsibility for results from using herbicides, whether or not they are used according to suggestions, recommendations, or directions of the manufacturer or any governmental agency.

CAUTION

Rates are for full coverage per acre. For spot or band treatments reduce rates in proportion to the area actually treated.

All rates are for silt and/or clay loam soils. Some residual herbicides **SHOULD NOT** be used on sandy soils. Others can be used on sandy soils at reduced rates. See label.

Crop	**Chemical or trade names and formulations**	**Amount of product per treated acre**	**Remarks**
Nonbearing blackberries, blueberries, grapes	Fusilade 2000 1E or Poast 1.5E	1 to 2 pt 1 to 2 pt	Annual and perennial grass herbicides. Use as a directed spray to actively growing grass 2 to 8 inches tall. Apply in 5 to 25 gpa water with 1 percent COC (2 pt/25 gpa) or 0.25 percent nonionic surfactant (1/2 pt/ 25 gpa). Do not apply within 12 months of harvest.

Crop	Chemical or trade names and formulations	Amount of product per treated acre	Remarks
Blackberries and raspberries	Princep 80W or Princep 4G or Sinbar 80W	2.5 to 5 lb 50 to 100 lb 1 to 2 lb	For plantings at least 1 year old. Apply in early spring before weeds emerge and before canes leaf out. On mowed-off Heritage, apply before new shoots emerge. Apply to soil surface at base of plants in a band along each side of the row. If winter weeds are a problem in established plantings, use half dosage in late fall and again in early spring. Treated area should not be disturbed or have untreated soil piled over it by cultivating equipment.
	Surflan 75W or Devrinol 50W	2.5 to 5 lb 8 lb	May be applied to new plantings after the ground settles and in a band over or along the row of established plantings in the spring before weeds emerge. Devrinol must be incorporated with 1/2 inch of rain or irrigation within 24 hours after application.
	Casoron 4G or Norosac 4G	100 lb	Use 4-percent granules. Apply any time from late fall to early spring to kill existing grass and weeds and to reduce growth of young weeds into early summer.

Crop	Chemical or trade names and formulations	Amount of product per treated acre	Remarks
Blackberries and raspberries, *continued*	Enide 90W	4.4 to 6.6 lb	Apply as a band application on new plantings of raspberries and blackberries. May be applied in the spring on established raspberries. Do not apply on raspberries within 60 days of harvest or on blackberries within 12 months of harvest.
	Gramoxone Super 1.5 (paraquat)	1.3 to 2.7 qt	Apply in spring before emergence of new canes or shoots.
Raspberries	Poast 1.5E	1 to 2 pt	A grass killer. Apply in 5 to 25 gallons of water per acre when grass is actively growing. Add 2 pints of oil concentrate per acre. Do NOT apply to raspberries within 45 days of harvest or to blackberries within 12 months of harvest.
Blueberries	Princep 80W or Princep 4G or Sinbar 80W	2.5 to 5 lb 50 to 100 lb 2 to 4 lb	See remarks under blackberries and raspberries. Apply in early spring. Princep and Sinbar may be applied on crops established at least 1 year.
	Surflan 75W or Devrinol 50W	2.5 to 5 lb 8 lb	May be applied to new planting after the soil settles and to bearing and nonbearing plants. See remarks under blackberries.
	Casoron 4G or Norosac 4G	100 lb	See remarks under blackberries and raspberries.

Crop	Chemical or trade names and formulations	Amount of product per treated acre	Remarks
Blueberries *continued*	Gramoxone Super 1.5 (paraquat)	1.3 to 2.7 qt	See remarks under black- berries and raspberries.
Grapes	Karmex 80W or Princep 80W	2 to 6 lb 2.5 to 6 lb	Use in vineyards established at least 3 years. Apply in early spring to soil under trellis in a band 30 inches wide.
	Devrinol 50W or Surflan 75W	8 lb 2.5 to 5 lb	May be applied to newly planted vines after the soil settles and to nonbearing and bearing vines. Devrinol must be incorporated within 24 hours by 1/2 inch of rain or irrigation or by shallow cultivation.
	Gramoxone Super 1.5E (paraquat)	1.3 to 2.7 qt	Apply as a postemergent spray when annual grasses and weeds become a problem. Keep spray off foliage. Use the sur- factant suggested by the manufacturer.
	Casoron 4G or Norosac 4G	100 to 150 lb	Use 4-percent granules. Apply from late fall to early spring to kill estab- lished weeds and grass. Residual effect to kill germinating weeds and grass will last until warm weather.
	Roundup 4EC	1 to 5 qt	Use as a directed spray in vineyards established at least 3 years or for site preparation prior to planting for control of emerged annual and perennial weeds. Keep spray off green foliage, green bark, and suckers.

Crop	Chemical or trade names and formulations	Amount of product per treated acre	Remarks
Strawberries	Dacthal 75W	8 to 12 lb	Preemergence action. May be applied immediately after planting or during the growing season to weedfree soil except when blossoms of fruit are present on beds to be harvested. Effective weed control usually lasts 4 to 8 weeks. Treatment may be repeated. Weak against velvetleaf, ragweed, smartweed, and nutsedge. Incorporate with 1/2 inch of rain or irrigation or shallow cultivation.
	Poast 1.5E	1 to 2 pt	A grass killer. Apply in 10 to 25 gallons of water per acre when grass is actively growing. Add 2 pints of oil concentrate per acre. Do NOT apply within 30 days of harvest. See label.
	Devrinol 50W	8 lb	Devrinol retards root development of runner plants; therefore it should not be applied until the desired number of runner plants is well rooted in both new plantings and in renovated plantings. An application in late fall just before mulching should last through harvest. May be incorporated with 1/2 inch of rain or irrigation within 24 hours.
	Gramoxone Super 1.5 (paraquat)	1.3 qt	Use as a directed spray to weeds between rows. Use shields to protect strawberry plants. No more than 3 sprays can be made per season. Do not apply within 21 days of harvest.

Crop	Chemical or trade names and formulations	Amount of product per treated acre	Remarks
Strawberries, *continued*	Sinbar 80WP	4 to 8 oz	Apply no more than 1 pound per year. May be applied at renovation if leaves are removed by mowing before spraying. Or apply to fully dormant plants from late fall to late winter. May apply 1/2 pound at renovation and again in late fall. Application rate must be accurate and must be adjusted to soil type and soil organic matter content. See label. Excess rates may cause serious injury. Growers using Sinbar for the first time should limit application to a small part of their plantings.
	2,4-D amine Formula 40	1 to 1.5 qt	Postemergence action. To control many broadleaf weeds in established plantings, apply in 25 to 50 gal of water per acre in late fall or early spring when strawberries are dormant. 2,4-D may also be applied at renovation time after last picking but before runners form. Do not use unless some crop injury is acceptable.

CAUTIONS

If you are applying herbicides for the first time or are trying a new herbicide, learn on a small area.

Avoid spray drifts. Use low pressure (30 to 60 pounds per square inch) with nozzles close to the ground. Spray when wind velocity is low.

Calibrate equipment to apply the correct amount of material per acre. Excessive amounts may cause damage to fruit plants. Lesser amounts may not give control. Uniform application is essential.

Clean sprayers after applying herbicides. Use detergent and water (2 cups in 25 gallons) or ammonia and water (1 quart in 25 gallons) to clean out wettable-powder sprays. Emulsifiable liquids should first be washed out with kerosene, then with detergent and water or ammonia and water. Do not allow drain solutions to run into streams or other water sources.

For herbicide suggestions in home fruit planting, see Circular 1144, *Controlling Weeds in Home Fruit Plantings*.

Controlling Weeds in Home Fruit Plantings

GRASSY AND BROADLEAFED WEEDS in home fruit plantings reduce yields, are unsightly, and may harbor injurious insects and mice. This publication is designed to aid home fruit growers in controlling these pest plants.

WEED CONTROL METHODS

Weed control methods available for the home fruit grower include using organic mulches, mowing, cultivating, hand hoeing, pulling weeds, and using herbicides. Usually a combination of these methods is the most practical approach.

MULCHING

Both tree fruits and small fruits, except strawberries, thrive under mulch culture (for strawberries, a modified mulch culture is suggested for winter protection). Organic mulches such as straw, hay, grass clippings, sawdust, hardwood bark, and chopped corn cobs are preferred. These mulches smother weeds, conserve moisture, reduce soil temperature fluctuations, and add organic matter to the soil. Keep the mulches about 6 inches deep. Because mulches may harbor mice, which damage fruit plants, use traps or bait or a good cat to keep mice under control.

CULTIVATING, HOEING, AND PULLING WEEDS

Cultivation is usually the most practical method of controlling the weeds and grass that grow in the aisles between rows of brambles, grapes, and strawberries. Hand hoeing and weed pulling will occasionally be needed to remove weeds that escape other control methods.

MOWING

The area between fruit trees usually is kept in bluegrass sod. Mowing is the most practical means of keeping weeds under control in this area. Mowing is also useful in the aisles between rows of grapes, blueberries, and brambles.

This circular was prepared by Daniel B. Meador, Associate Professor of Pomology Extension, and C. Chris Doll, Area Extension Adviser in Fruits and Vegetables.

HERBICIDES

Herbicides (chemical weed killers) can be used safely in home fruit plantings if the directions are followed carefully. Residual-type herbicides must be applied in the correct amount per area. Exceeding the recommended rate may damage fruit plants; using less than the recommended rate may not control weeds. Do not use residual-type herbicides on sandy soils.

ECONOMICS OF CHEMICAL WEED CONTROL

Chemical weed control probably is not practical for home gardeners with small plantings of fruit plants. Mulching, cultivation, hoeing, and weed pulling are the most practical weed control methods for small plantings.

Gardeners with larger plantings may find chemical weed control economically feasible. Farm families may currently be using some of the suggested herbicides in their farming operations and thus may already have them on hand.

Most of the herbicides suggested are packaged in 4- or 5-pound bags for wettable powders or in gallon containers for liquids. Purchasing that much herbicide represents a considerable investment. Herbicides will retain their effectiveness over several years, however, if they are stored in a dry area.

SUGGESTED HERBICIDES

The herbicides suggested in this circular are wettable powders (W), granules (G), or liquid emulsifiable concentrates (EC). Wettable powders and liquids are mixed with water for application. Granular herbicides are applied in the dry form.

Oryzalin (Surflan), simazine (Princep), DCPA (Dacthal), and diphenamide (Enide) are residual-type herbicides. Like most residual types, they work primarily against germinating weeds but have little or no effect on existing weeds. Any existing weeds should be removed by cultivation or killed with a contact-type herbicide before applying residual herbicides.

Dichlobenil (Casoron) is a residual herbicide that also has excellent eradicative action (kills existing weeds). It is volatile in hot weather and loses its effectiveness by early summer. When applied in late fall, winter, or early spring, Casoron kills existing weeds and acts as a residual herbicide against germinating weeds. It is especially useful in cleaning out weedy patches of raspberries, blackberries, and blueberries.

Residual herbicides do not become active until they are incorporated into the top layer of the soil. A half-inch of rain or irrigation water is sufficient for incorporation. These herbicides will be effective against new weed seedlings for varying lengths of time. Cultivation destroys their effectiveness. None of the residual herbicides is effective against all species of weeds; some hand hoeing and weed pulling will be necessary. Do not use residual-type herbicides on sandy soils.

Paraquat (Gramoxone), a nonselective contact-type herbicide, burns any foliage it contacts. It is useful under fruit trees and grapevines where the weeds can be sprayed without getting any spray material on the leaves of the fruit plants. Paraquat has been listed as a restricted pesticide by the Environmental Protection Agency; therefore, sale and use are limited to certified private applicators.

Amine 2,4-D is a growth-regulator-type herbicide that is effective against many species of broadleafed weeds. It can be used under apple and pear trees as needed; at certain times of the year, it can be used on strawberries.

Glyphosate is marketed as Roundup (4 pounds per gallon EC) and under other trade names in less concentrated form, one of which is fully diluted for use. Glyphosate is a non-selective growth-regulator-type herbicide that is effective against annual and perennial grasses and weeds. Keep glyphosate off the foliage of fruit trees.

WHERE TO BUY

Farm supply stores frequently carry paraquat, Princep, Dacthal, Surflan, Roundup, and amine-type 2,4-D. In areas where vegetables and fruits are produced commercially, these stores may also carry Enide and Casoron.

Garden centers and seed stores frequently carry Dacthal and amine-type 2,4-D. Some of them may also have Princep, Enide, Casoron and formulations of glyphosate.

WEED CONTROL PROGRAMS

FRUIT TREES

Young fruit trees need to be protected from competition by weeds for five years after planting. Organic mulches, cultivation, or herbicides may be used.

If the mulch program is to be used, apply the mulch soon after planting. Cover all the soil within 2 feet of the trunk. As the trees grow, the mulch may be extended to cover the area under the branches. If the mulch is maintained, cultivation or herbicides will not be needed.

If newly planted trees are not mulched, the soil within 2 feet of the trunk should be cultivated shallowly during the first growing season. The cultivated area may be larger if desired.

After the first growing season, cultivation or mulching may be continued or herbicides may be applied. The residual herbicides Princep or Surflan should be applied in the spring to bare soil or to areas where the existing weeds have been killed with paraquat or Roundup. The herbicide may be applied to a circular area extending 3 feet from the trunk, or to an area 4 feet square with the tree in the center, or to a 3- to 4-foot-wide strip down the tree row.

Starting with the sixth growing season, mulching or herbicide application may be continued, or closely mowed grass can be allowed to grow under the trees. A 12-inch-wide gravel or sand collar around each tree prevents the growth of weeds and grass next to the trunk and eliminates the possibility of mower injury to the trunk.

Apples and Pears

Princep 4G........	3½ ounces treats 100 square feet
	2 pounds, 4 ounces treats 1,000 square feet
Princep 80 W	1 teaspoon treats 34 square feet
	1 tablespoon treats 102 square feet
Surflan 75 W	1 teaspoon treats 31 square feet
	1 tablespoon treats 93 square feet
Paraquat..........	See section on paraquat
Amine 2,4-D	See section on 2,4-D
Casoron 4G........	5½ ounces treats 100 square feet
	3 pounds, 7 ounces treats 1,000 square feet
Roundup	See section on Roundup

Peaches, Cherries, Plums, and Apricots

Princep 4G........	Same as apples
Princep 80 W	Same as apples
Surflan 75 W	Same as apples
Paraquat..........	See section on paraquat
Casoron 4G........	Same as apples
Roundup	See section on Roundup

Suggestions and restrictions. Princep or Surflan: Apply in spring or early summer to bare ground, or apply soon after paraquat or Roundup has been used to control existing foliage. Do not apply on trees established less than one year. Make only one application per year.

Casoron: Apply in late fall, winter, or early spring. Make only one application per year.

BLACKBERRIES, RASPBERRIES, AND BLUEBERRIES

During the first growing season after planting, these plants should be mulched or cultivated. Mulching is preferred because it reduces the need for watering. However, the mulch must not be so deep that it prevents the new shoots from coming through. This is especially important for blackberries and red raspberries, which send up new shoots several inches from the main plant. During the second growing season and subsequent seasons, mulching or cultivation may be continued or herbicides may be used.

Casoron is especially useful to clean out existing weeds. It is also effective against germinating weeds until hot weather.

Surflan or Princep should give fairly good weed control throughout the growing season. In southern Illinois, foxtail and fall panicum may grow through the herbicide band in late summer.

Princep 4G........	3½ ounces treats 100 square feet
	2 pounds, 4 ounces treats 1,000 square feet
Princep 80 W	1 teaspoon treats 34 square feet
	1 tablespoon treats 102 square feet
Surflan 75 W	1 teaspoon treats 31 square feet
	1 tablespoon treats 93 square feet
Casoron 4G........	3½ ounces treats 100 square feet
	2 pounds, 4 ounces treats 1,000 square feet

Suggestions and restrictions. Princep and Surflan: Apply to weed-free soil in the spring before berry plants leaf out. Do not apply to plants established less than one year. Make only one application per year.

Casoron: Apply in late fall, winter, or early spring to plants established at least 6 months. Make only one application per year.

GRAPES

Grapes should be mulched or cultivated during the first three growing seasons. During the fourth and subsequent growing seasons, mulching or cultivation may be continued, or Surflan, Princep, or Casoron may be applied to a 3- to 4-foot wide strip down the row. Apply Surflan or Princep in the spring. Casoron should be applied in late fall, winter, or early spring. Paraquat and Roundup may be applied during the growing season as needed for weed knockdown.

Princep 4G........	4½ ounces treats 100 square feet
	3 pounds, 7 ounces treats 1,000 square feet

Princep 80 W	1 teaspoon treats 34 square feet
	1 tablespoon treats 102 square feet
Surflan 75 W	1 teaspoon treats 31 square feet
	1 tablespoon treats 93 square feet
Paraquat..........	See section on paraquat
Casoron 4G........	5½ ounces treats 100 square feet
	3 pounds, 7 ounces treats 1,000 square feet
Roundup	See section on Roundup

STRAWBERRIES

Immediately after planting, Dacthal can be applied. It is more effective against grasses than against broadleafed weeds and is effective for about six to eight weeks. When Dacthal loses its effectiveness, clean the patch by cultivation and hoeing and apply again or switch to Enide. Enide has a much longer effective period than Dacthal and is likewise more effective against grass than against broadleafed weeds.

From planting time until runners start to form, many growers find cultivation and hoeing to be the most economical and successful weed control program. When the runner plants begin to root in late June or July, cultivation must be reduced; at this time, either Dacthal or Enide may be applied. If Dacthal is used, it can be applied again in September. If Enide is applied, it should be effective until late fall.

The effectiveness of Dacthal and Enide is destroyed by cultivation. After application of either of these materials, use a hand hoe or hand pulling to remove any weeds that were missed. Do not cultivate until just before you are ready to make another herbicide application.

In late November just before mulching, apply Enide. This application should give control through the harvest season. If dandelions and other perennial weeds are present, amine 2,4-D may also be applied.

At renovation time, immediately after harvest, when the rows have been narrowed and weeds in the aisles have been destroyed by cultivation, apply Dacthal or Enide. Enide should be effective until late fall. If Dacthal is applied, apply again in six to eight weeks. If broadleafed weeds are present in the rows at renovation time, amine 2,4-D may be applied.

Follow with an application of Enide just before mulching, as suggested above. In subsequent years, apply herbicides at renovation time and in late November before mulching.

Dacthal 5G	6½ ounces treats 100 square feet
	4 pounds treats 1,000 square feet
Dacthal 75 W	1 teaspoon treats 16 square feet
	1 tablespoon treats 48 square feet
Enide 90 W	1 teaspoon treats 32 square feet
	1 tablespoon treats 96 square feet
Amine 2,4-D.......	See section on 2,4-D

Suggestions and restrictions. Do not apply Dacthal when blossoms or berries are present. Do not apply Enide within 60 days before harvest, and do not apply more than twice a year. Amine 2,4-D may be applied immediately after harvest or in late fall but not at other times.

APPLYING WETTABLE POWDER RESIDUAL HERBICIDES

To be effective against germinating weeds without substantially injuring fruit plants, an exact amount of the herbicide must be spread evenly on an exact area of the soil. Recommendations for wettable powder herbicides in this circular give amounts in teaspoons or tablespoons to be spread evenly over square foot areas (length × width). For smaller areas, use ½ teaspoon or ¼ teaspoon measures and calculate the area to be covered by dividing the area for 1 teaspoon by 2 or by 4, respectively. For larger areas, multiples of 1 tablespoon may be used.

For most wettable powder applications a sprayer is the most convenient equipment. Use a flat fan type nozzle. For small areas a sprinkling can may be satisfactory.

The first step in application is adjusting the equipment to fit the situation. First, look up the amount of material required for a given area (see the section for each crop). Next, stake out the given area. If 1 tablespoon of material is suggested for 50 square feet, stake out an area of 50 square feet. Then make a trial run with the sprayer using water *only*. Try 1 quart of water. Spray evenly over the staked out area until all of the water is used. After the first trial run you may wish to increase or decrease the amount of water. After you have adjusted the amount of water to an amount convenient for covering the staked out plot, you are ready to apply the residual herbicide.

Measure the required amount of herbicide using a measuring teaspoon or tablespoon. Regular teaspoons and tablespoons used for eating and serving food do *not* measure accurately. Do not pack the material into the measuring spoon. Dip the measuring spoon into the material, overfilling the spoon. Then use a spatula or knife to remove the excess material, leaving the measuring spoon level full.

Place the measured amount of herbicide and the measured amount of water in the sprayer. Close the sprayer and shake vigorously to mix. Shake the sprayer while spraying to keep the materials mixed. Spray all of the material evenly on the staked out area.

Example: Applying Enide 90 W to strawberries. The recommended rate is 1 tablespoon per 96 square feet. If the rows are 3½ feet wide, stake out an area 3½ feet by 27 feet. Make a trial run with water only, using 1 quart of water. If 1 quart of water is convenient for coverage of the staked out area, put 1 tablespoon of Enide 90 W and 1 quart of water in the sprayer, shake thoroughly to mix, and spray evenly over the staked out area, using all of the spray mixture.

APPLYING GRANULAR RESIDUAL HERBICIDES

In granular formulations, the herbicide is incorporated onto an inert material and made into small granules. A fertilizer spreader or seeder is used to spread the material evenly over a specified area.

A lawn fertilizer spreader that drops the material in a band is convenient for applying granular materials under fruit trees and on strawberry beds. To calibrate this type of spreader, spread a sheet of plastic on a smooth area such as a driveway. Then run the spreader over a measured distance and determine the amount of material spread over the square foot area covered.

Example: Applying Dacthal 5G to strawberries. The recommended rate is 6½ ounces for 100 square feet or 4 pounds per 1,000 square feet. Set the dial for 4 pounds per 1,000 square feet; but since materials vary in density, test to determine the actual delivery rate. Spread a plastic sheet on the driveway, mark off 10 feet, and spread a 10-foot strip. Sweep up the material and weigh. If the material delivered weighed 3 ounces and the width of the band was 3 feet, then the rate was 3 ounces spread on 30 square feet (10 ft. long × 3 ft. wide). This would be a rate of 10 ounces per 100 square feet, which is too much. Reduce the size of the delivery holes and try another test strip. Continue adjusting and measuring delivery on the test strip until 2 ounces are delivered on the 30-square-foot test strip.

The cyclone-type spreader or seeder is more difficult to calibrate because walking speed is a part of the calibration. Rather than calibrate the spreader and speed of walking, a different approach is suggested. Set the opening to deliver the material slowly so that you must make two or more trips over the area to apply the given amount of material. Determine the number of square feet to be treated and calculate the amount of granular material needed. Put this amount of material in the spreader and go over the area to be treated until all of the material is used up.

APPLYING PARAQUAT, 2,4-D, AND ROUNDUP

PARAQUAT

Use 1 tablespoon of paraquat plus 1 teaspoon of a wetting agent per gallon of water. Wet the weed and grass foliage. Keep off foliage of fruit plants. The wetting agent may be a regular spreading agent or a liquid dishwashing agent such as Lux, Vel, etc. Paraquat may be applied more than once during the growing season.

Because paraquat has been listed as a restricted pesticide by the Environmental Protection Agency, purchase and use are limited to certified private applicators.

2,4-D

Use 1 tablespoon of amine 2,4-D plus 1 teaspoon of wetting agent (see the preceding paragraph) per gallon of water. Wet the foliage of broadleafed weeds under apple and pear trees, but keep off apple and pear foliage. In strawberry beds, wet the foliage of both broadleafed weeds and strawberry plants.

Tomatoes and grapes are extremely sensitive to vapors from 2,4-D sprays. During the growing season, do not spray 2,4-D near these plants — keep at least 100 feet away.

ROUNDUP AND OTHER FORMULATIONS OF GLYPHOSATE

Apply as a wipe on weeds under fruit trees and grape vines. Can also be applied as a spray under apple, pear, and cherry trees and under grape vines. Remove any suckers before spraying. Keep off fruit plant foliage. See label for directions.

PRECAUTIONS

1. Choose a calm day to apply herbicides. Winds cause drift to other plants and other areas and prevent even coverage.
2. Use low pressure in the tank or pump.
3. Use flat fan weed spray nozzles.
4. Read and follow all precautions listed on the product label.

Controlling Weeds in the Home Garden

A weed is a plant growing where it is not wanted. Weeds compete with desirable plants for water, soil nutrients, sunlight, and gaseous components of the air needed for growth. Many weeds also harbor diseases and insects that may attack plants around the home.

Three general methods of weed control can be used in the home garden: (1) cultivation and mechanical removal (hoeing, pulling); (2) mulching (smothering of weeds); and (3) herbicides (weed killers). Usually, one or more of these methods is used.

CULTIVATION AND MECHANICAL REMOVAL

Cultivation and mechanical removal are the safest and most common method for controlling weeds in small home gardens. Since only those weeds that are actually present can be controlled, the process must be repeated several times throughout the growing season. It may be difficult to control weeds adequately with this method during vacations or busy work periods.

Shave off deeply rooted weeds with a sharp hoe while gently breaking up the soil crust. Deep tillage can cause severe injury to shallow-rooted plants and can bring deeply buried weed seeds to the surface where they can germinate. Keeping equipment sharp and in good condition will help to reduce injury to desirable plants. Hoe carefully around your plants, and hand pull weeds close to the plants.

Weeds in small areas can be controlled by wheel hoes or hand hoes; in large gardens use power equipment such as rototillers and garden-type tractors. This equipment should be set shallow when used in a garden for weed control. Avoid cultivating too close to crop plants in order to prevent root injury.

MULCHING

Mulching controls weeds by preventing light from reaching the weed seeds or seedlings. This method will control many annual weeds--those that germinate from seed each year. Perennial weeds (those that sprout each year from belowground plant parts) usually must be removed by cultivation or hoeing.

The advantages of mulching include moisture conservation, prevention of soil crusting, reduction of erosion, increased spring soil temperatures, and the ability to keep edible aboveground plant portions clean.

Revised by D.J. Williams
1988 Revision of
Circular 1051

ORGANIC MULCHES

The organic materials used most frequently for mulching include plant residues such as straw or hay (free of weed seeds); crushed corncobs; various nut hulls; leaf and grass composts; peat; wood products such as sawdust, wood chips, shredded bark, and shavings; and well-rotted animal manures. Use the most economical mulch available. A combination of several thicknesses of newspaper (use papers with black ink, not colored ink) covered by organic materials has shown promise as a type of summer mulch. For good results, apply these materials to a depth of four to six inches.

Applying in natural mulch materials may require considerable hand labor. Most organic materials are bulky and must be hauled to the place of use, but this is not a serious problem in small gardens.

As organic mulches decompose, they return organic matter and some plant nutrients to the soil and improve soil tilth. Added benefits are the prevention of soil compaction, conservation of soil moisture, erosion control on slopes, cooler summer soil temperatures, and added attractiveness of the garden.

When organic materials are used, you may need to add nitrogen fertilizer to prevent a deficiency of nitrogen in the mulched crop. With alfalfa, clover, or other legume mulches, however, excess nitrogen is released during decomposition.

Organic mulch materials	Nitrogen required for decomposition (pounds per ton of mulch)
Cocoa pods	6.0
Corncobs (ground)	22.5
Hay, grass clippings	7.6
Peanut hulls	8.5
Sawdust (fresh)	26.0
Wheat straw	17.6

SYNTHETIC MULCHES

Common synthetic mulches include polyethylene, paper, paper-polyethylene combinations, black polypropylene mats, fiberglass mats, wax-coated papers, and aluminum and steel foils.

Polyethylene film is used in a thickness of 1 to 1 1/2 mils (1 mil = 0.001 inch) and a width of three to six feet. Black polyethylene is preferable for the home vegetable garden because it prevents light from reaching the weed seedlings. It is generally not practical to use transparent polyethylene as a full-season mulch because weeds develop under the polyethylene.

To install, press the edges of the mulch down into furrows and cover them firmly with soil. A push-type, one-wheel cultivator works well to open and close furrows. The mulch may also be installed by using a rake or shovel to cover the edges with soil. Do not throw excess soil on top of the mulch.

It is better to apply synthetic mulches in crop rows than to attempt to cover the entire area. The area between the rows of polyethylene mulch must be carefully cultivated or hoed.

Use of polyethylene mulch will increase spring soil temperatures and hasten the development of some crops.

HERBICIDES

It is not a good practice to use herbicides in small ornamental and vegetable gardens containing several crop species because different flowers, vegetables, and weeds vary in their tolerance to herbicides. Some herbicides may remain in the soil longer than one growing season and may kill or injure some species the following year (especially if excessive rates are used). Ideally, a specific herbicide should be used for each crop species, but most people have small areas of several species in their gardens, and it would often be impractical and expensive to buy the several herbicides that would be needed.

Application must be carefully controlled when a herbicide is used on small areas. The tendency is to apply additional amounts if the quantity measured out "looks" as if it is not enough. A low percentage granular formulation is suggested for small garden areas. *CAUTION: Check the container label very carefully for rates of material to use and application techniques. Applications must be accurate and uniform. Excessive amounts may cause injury to the present or subsequent crops.*

If a gardener prefers not to remove weeds by hand in the home garden, Dacthal, Amiben, Treflan, Genep, or Eptam can be used on several species. These herbicides may not be the most effective for a large planting of the individual fruit or vegetable species. Herbicides for these large plantings are listed in Extension Circular 907, *Weed Management Guide for Commercial Vegetable Growers*, in *1988 Herbicides for Commercial Small Fruits*, and *1988 Herbicides for Commercial Tree Fruits*, all of which are revised annually and appear elsewhere in this *Handbook*.

Trade name	Common name	Chemical name
Dacthal	DCPA	dimethyl 2,3,5,6-tetrachloroterephthalate
Roundup, Kleenup	glyphosate	*N*-(phosphonomethyl)glycine
Treflan, Preen	trifluralin	α, α, α-trifluoro-2,6 dinitro-*N*-*N*-dipropyl-p-toluidine
Devrinol	napropamide	*N*,*N*-Diethyl-2-(1-napthalenyloxy)-proprionamide
Amiben, Weedone Garden Weeder, Ornamental Weeder	chloramben	3-amino-2,5-dichlorobenzoic acid
Eptam, Genep	EPTC	ethyl *N*,n-dipropylthiolcarbamate
Dalapon 85, Dowpon M (and others)	dalapon	2,2 dichloropropionic acid

Herbicides may be sold under several trade names. If you cannot identify the trade names on the container, look on the label for the common name or the chemical name of the active ingredients. The trade names listed in this publication are for products commonly used in Illinois. Products of identical content that are marketed under other trade names may be equally effective.

DCPA

DCPA is a preemergence herbicide that controls very small weed seedlings soon after the weed seeds germinate. It does not control weeds that have emerged prior to application. The herbicide action is most effective if rainfall occurs or the soil is irrigated within two to three days after application of the herbicide. Weeds that have already emerged should be removed before DCPA is applied.

DCPA is the best *multipurpose* herbicide for home-garden use. It is available as a 75 percent wettable powder and as a 5 percent granular formulation. DCPA can be used for annual grass control in lawns, on a number of species of flowers, and on strawberries, broccoli, brussels sprouts, cauliflower, cabbage, dry and snap beans, cucumbers, squash, melons, collards, kale, mustard greens, turnips, garlic, onions, potatoes, sweet potatoes, yams, tomatoes, eggplants, peppers, and horseradish.

Do not use DCPA on beets, bugle weed, button pink, carnation, geum, germander, mesembryanthemum, pansy, phlox, sweet william, and telanthera.

A one-time application to all species is not always possible in a garden of flowers or vegetables because some plants are susceptible to injury when they are in early growth stages. It is preferable to use DCPA at seeding or transplanting time if the species is adapted for it. When application must be delayed, remove emerged weeds and then apply Dacthal to prevent further weed development. Consult the container label for the appropriate application time.

DCPA is effective in controlling annual grasses that are a problem in the spring. Broadleaf weeds must be removed mechanically.

Trifluralin

Because trifluralin is used in soybean production in Illinois, it is widely available. It can be purchased as a liquid with four pounds of active ingredient per gallon for large areas or in a low-percentage granular form for smaller areas.

Trifluralin can be used for weed control in green, lima, and dry beans, broccoli, brussels sprouts, cabbage, cauliflower, carrots, kale, mustard greens, okra, peas, peppers, tomatoes, turnip greens, apricots, cherries, grapes, peaches, and plums. Established trees, some ornamentals, and many established flowers will tolerate trifluralin. Do not use trifluralin on ground covers, sweet corn, strawberries, bramble fruits, or blueberries, because injury may result.

Trifluralin must be moved into the soil soon after application in order to prevent loss of the chemical from the soil surface. A rototiller or similar equipment should be used to mix trifluralin with the soil to a three- to four-inch depth. When it is impractical to mix trifluralin with the soil mechanically, all emerged weeds should be removed and the herbicide should be incorporated into the soil by rainfall or sprinkle irrigation.

The correct amount of trifluralin to use depends on the type of soil to which it is being applied. The appropriate amounts are shown on the container label.

Trifluralin is quite effective on annual grasses, but many broadleaf weeds will need to be removed mechanically.

Napropamide

Napropamide is a preemergence herbicide. It should be incorporated into the soil by mechanical means or irrigation. Control existing weeds before applying napropamide.

Napropamide can be used in asparagus, tomatoes, peppers, strawberries, tree fruits, nuts, shrubs, and shade trees. It will control annual grasses such as barnyardgrass, crabgrass, fall panicum, and goosegrass. Broadleaf weeds that can be controlled by napropamide include carpetweed, purslane, lambsquarters, and pigweed.

Chloramben

Chloramben is available to many Illinois gardeners because it is used in soybean production. It should be applied to the soil surface before weed seeds germinate. The herbicide action is most effective if rainfall occurs or the soil is irrigated within two to three days after application of the herbicide.

Chloramben is available as a liquid with two pounds of active ingredient per gallon for large areas and as a low-percentage granular material for small areas. It can be used on lima beans, pumpkins, squash, sweet potatoes, transplanted tomatoes and peppers, and on young asparagus beds when they will not be harvested that season. Chloramben can be used on cucumbers, green beans, and muskmelons, but some injury may occur to these vine crops. Do not use chloramben on other vegetable or fruit crops.

As indicated on the container label, a number of annual flowers and established shrubs will tolerate chloramben. Chloramben controls a wider range of annual grass and broadleaf weeds than do DCPA, trifluralin, or EPTC, but it is not as effective on common purslane, which is often a problem in home gardens.

Chloramben is quite soil mobile and should not be used on gardens in sandy soil.

EPTC

EPTC can be purchased as a liquid with seven pounds of active ingredient per gallon for large gardens or as a 10 percent granular material for smaller areas. It can be used for weed control in green beans, dry beans, and Irish potatoes.

EPTC must be mixed with or watered into the soil immediately after application to prevent loss of the chemical from the soil surface. A rototiller or similar equipment should be used to mix EPTC with the soil to a three- to four-inch depth. When it is impractical to mix EPTC with the soil mechanically, all germinated and growing weeds should be removed, and the herbicide should be incorporated into the soil by rainfall or sprinkle irrigation.

EPTC is quite effective on annual grasses, but most broadleaf weeds will need to be mechanically removed.

Perennial Weed Control

Cultivation and mulching do not control most perennial weeds. Perennials can be controlled by removing the top growth to deplete the food (carbohydrate) supply in the underground storage tissues. This method may suppress the growth of perennial weeds, but completely eradicating the weeds with this method requires frequent recutting of the top growth.

Glyphosate (Roundup, Kleenup) must be applied to the foliage of green, actively growing plants to be effective. It has no soil activity, so it can be applied in the early spring. It can also be applied in the fall, after the edible plants have been removed from the garden, but while the perennial weeds are still growing. Do not apply glyphosate to (or let it drift onto) desirable or edible plants since it is nonselective. Be sure to read the label for complete application instructions.

Glyphosate can be used to control perennial weeds in vegetable gardens where labeled vegetable species will be grown. It must not be applied where nonlabeled vegetable species are to be grown. If gardeners in areas that are infested with perennial weeds are willing to restrict their choice of crops for one year, this method can effectively reduce the weeds. To find out which species are labeled, check the glyphosate label or ask your Extension adviser.

PRECAUTIONS

General

Phenoxy herbicides (2,4-D and others) and dicamba (Banvel) are used to control broadleaf weeds in corn, turf areas, and roadways. Most flowers, shrubs, shade trees, small fruits, tree fruits, and vegetables are susceptible to injury by these herbicides. When applying these materials, be sure that direct spray, drifting spray, or fumes do not reach susceptible plants.

Use the amine formulation of 2,4-D, which is less volatile and does not drift as easily as the esters, and apply it under calm conditions and temperatures below 80°F to 85°F. A sprayer used to apply phenoxy herbicides or dicamba on grass should not be used to apply other pesticides on gardens. Phenoxys usually cannot be cleaned out of sprayers thoroughly enough to avoid injury to broadleaf plants.

Soil Deactivation

If a garden area becomes contaminated with a persistent herbicide or a soil sterilant, this area can be decontaminated by applying activated carbon to inactivate the herbicide. See Horticulture Fact Sheet VC-15-81, *Testing for and Deactivating Herbicide Residues*.

Disposal of Pesticide Containers and Surplus Pesticides

Use pesticides safely. Read the label. If pesticides are handled or applied improperly, or if unused containers are disposed of improperly, injury can occur to humans, domestic animals, desirable plants, pollinating insects, and fish or other wildlife. Water supplies can also become contaminated. Use pesticides only when needed, and handle them with care. Follow the directions, and heed all precautions on the container labels.

Store all pesticides in a cool, dry, locked storage area so that they are not accessible to children, unknowledgeable persons, or animals. Do not dispose of pesticides through sewage systems or where they can run off into drainage ditches or bodies of water. Haul them or have them hauled to a sanitary landfill for burial.

Never place aerosol cans on a stove or heater or near any source of heat that might exceed 120°F. Store in a cool place--not in the hot sun. Have empty aerosol cans hauled away and buried by experienced disposal crews. *Do not incinerate aerosol cans.*

Classification of Herbicides

The U.S. Environmental Protection Agency classifies herbicides for *general use* or *restricted use*. An Illinois resident wishing to use a herbicide classified for restricted use must be certified as a private or commercial pesticide applicator by the Illinois Department of Agriculture. Your county Extension adviser in agriculture can give you details on this program. None of the herbicides discussed in this article have been classified for restricted use.

Controlling Weeds in Noncrop Areas

D. Anderson and M. McGlamery

Total vegetation management is the application of nonselective chemicals or nonselective rates of selective chemicals as a means of controlling all vegetation in such noncrop areas as parking lots, drive-in theater lots, driveways, and certain industrial sites.

Herbicides can be classified by their length of control. Those with little or no residual activity are the fumigants and the contact herbicides. Fumigants are volatile materials that can affect existing growth and the viability of weed seeds. Contact herbicides, such as paraquat, control only the existing vegetation that the spray contacts.

Amitrole, dalapon, 2,4-D, and DSMA give residual control for four months or less. Longer, semipermanent control is provided by some inorganic salts, such as sodium borate and sodium chlorate. Organic compounds that provide semipermanent control are bromacil, diuron, tebuthiuron, and the triazines (atrazine, simazine, and prometon).

Total vegetation management is desirable along fences, beneath asphalt pavement, along railroads, and around buildings as a means of preventing the growth of weeds that are unsightly or weeds that present a fire hazard. As an alternative to chemical control in some noncrop areas, it may be preferable to establish desirable, competitive vegetation to discourage weed growth and to provide protective soil and wildlife cover. Herbicides with little or no residual activity can be used for temporary control until desirable vegetation is established.

PRECAUTIONS AND GENERAL PROCEDURES

Several precautions must be observed when nonselective chemicals are used. Know what weeds are to be controlled and select the correct chemical for those particular problems. Survey the area, noting any desirable vegetation in the immediate or adjacent areas that could be affected by spray drift, chemical runoff, or herbicide leaching into the root zone.

Appropriate precautions should be taken to prevent damage to desirable plants. The risk of injury with some of these materials may be too great to allow their use in some areas. Be certain that you are familiar with the product and be aware of the risks before using any of these herbicides. Some treatments should be made only by professional applicators.

The type of vegetation to be controlled will affect your choice of a chemical. For example, perennial grasses can be controlled with dalapon, amitrole, pronamide, asulam, or DSMA; woody perennials can be controlled with picloram, triclopyr, 2,4-D, or Krenite. Deep-rooted vines, such as bindweed, can be controlled with dicamba or picloram.

Application timing is very important. The best time to apply nonselective, soil-residual herbicides is early in the spring before herbaceous weeds have emerged. If vegetation is dense, it may be necessary to mow or cut existing vegetation. For a later application, add a contact or translocated foliar herbicide, or mix the herbicides with diesel fuel to speed topkill. Follow label recommendations. After existing vegetation is under control, the rate of the soil herbicides can be reduced for maintenance applications.

Adjust application rates according to the soil type or the desired length of control. When you want to control growth for two or three years, several maintenance applications are better than one initial treatment at a high application rate.

HERBICIDES FOR NONCROPLAND

Inorganic Herbicides

1. **Sodium chlorate** has both foliar and root activity. The rate is 500 to 1,000 pounds per acre. This compound presents an *extreme fire hazard*, so fire retardants, such as calcium chloride or the borates, are often added to reduce the hazard. Altacide is sodium chlorate with a fire retardant. Another drawback to sodium chlorate is that it may be toxic to livestock that seek its salty taste.

2. **Sodium borate** (Borox, Polybor) has primarily root activity. Very high rates are required (1 to 2 tons per acre), so it is often used only as a granular carrier for organic compounds.

3. **Sodium arsenite** is a *highly toxic* compound. It is not usually recommended because safer products are now available. Sodium arsenite is formulated as a 9.5-pound-per-gallon liquid. The rate is 55 to 110 gallons per acre.

Organic Herbicides for Long-Term Control

1. **Asulam** (Asulox) is a 3.34-pound-per-gallon formulation that is used at the rate of 1 to 2 gallons per acre. Asulam controls grasses more effectively than it controls broadleaf weeds.

2. **Bromacil** (Hyvar-X) has both foliar and soil activity. It is formulated as an 80 percent wettable powder (WP) and a 2-pound-per-gallon liquid. Urox-'B' is a 4-pound-per-gallon liquid of bromacil. The rate of active ingredient is 5 to 15 pounds per acre.

3. **Bromacil + diuron** (Krovar I) is formulated as an 80 percent wettable powder or dry flowable, 1:1 combination of bromacil:diuron. It is used to control shallow-germinating weeds and deep-rooted perennials. The rate is 6 to 30 pounds per acre. Krovar II is a 2:1, bromacil:diuron dry flowable formulation.

4. **Simazine** (Princep) is formulated as an 80 percent WP, a 4-pound-per-gallon liquid, a 90 percent water-dispersible granule (WDG), and a 4 percent granule (G). It has little foliar activity but has longer residual control than atrazine. The rate is 6 to 22.5 pounds per acre of the 80 percent WP.

5. **Atrazine** is an 80 percent WP, a 4-pound-per-gallon liquid, or a 90 percent WDG. Atratol 8P is 8 percent atrazine on a chlorate-borate pellet, and Atratol 90 is a 90 percent WDG. The rate is 6 to 50 pounds per acre of the 80 percent WP, 0.25 to 1 pound per 100 square feet of the pellet, or 0.12 to 1 pound per 1,000 square feet of the water-dispersible granule.

6. **Prometon** (Pramitol) is available as a 2-pound-per-gallon liquid (Pramitol 25E) and a 5 percent pellet (Pramitol 5PS). Prometon has more foliar activity than atrazine. The rate for the liquid is 5 to 30 gallons per acre. The pellet rate is 0.5 to 2 pounds per 100 square feet.

7. **Hexazinone** (Velpar) is available as a 90 percent water-soluble powder (WSP), a 25 percent liquid (L), and a 75 percent granular formulation (G). Apply 2 to 5 pounds WSP or 1 to 2 1/2 gallons L per acre for contact kill and short-term control. Hexazinone is highly water soluble and may run off to damage vegetation in adjacent areas.

8. **Tebuthiuron** (Spike) is available as an 80W in water-soluble packets, as an 85DF, and as 5, 20, and 40 percent granules (5G, 20P, and 40P, respectively). Activity becomes apparent during the growing season within a few days after sufficient rainfall has moved Spike's active ingredient into the root zone. Use rates are 4.75 to 7.0 pounds per acre of 85DF, 1.25 to 7.5 pounds per acre of 80W, 20 to 120 pounds per acre of 5G, 3.75 to 30 pounds per acre of 20P, and 2.5 to 15 pounds per acre of 40P. Tebuthiuron is also available in a prepack with trifluralin as Spike-Treflan 6G. This product offers additional grass control and is applied at rates from 100 to 200 pounds per acre.

9. **Diuron** (Karmex) is an 80 percent DF. The rate is 10 to 60 pounds per acre. It is sometimes mixed with bromacil (described earlier in 3).

10. **Dichlobenil** (Casoron) is available as a 50 percent WP and as 4 percent granules. It is used more commonly for nursery weed control than for soil sterilization. The rate is 10 to 40 pounds per acre of the 50 WP.

11. **Amizine** is amitrole plus simazine, which combines the foliar activity of amitrole with the residual activity of simazine. The suggested rate for general vegetation control is 20 pounds of Amizine per acre in 100 gallons of water or 9 gallons of Liquid Amizine per acre in a minimum of 50 gallons of water. Amizine and Liquid Amizine are restricted-use pesticides.

12. **Chlorsulfuron** (Telar) is a 75 percent DG that is most effective when applied postemergence, but it is also labeled for preemergence application. The rate is 1/4 to 3 ounces per acre.

13. **Sulfometuron** (Oust) is a 75 percent DG that is labeled for preemergence and postemergence application to young weeds. The rate is 1 to 12 ounces per acre.

14. **Imazapyr** (Arsenal) is formulated as a 2-pound acid equivalent-per-gallon aqueous solution that is taken up by both foliage and roots and translocated throughout plants. It controls annual and perennial grasses and broadleaves and, at the higher rates, brush species. Labeled rates range from 2 to 6 pints per acre. Arsenal can be applied preemergence or postemergence, but

postemergence application is the method of choice, especially to control perennials. Arsenal usually provides residual soil activity after a postemergence application. Prevent drift to desirable plants. Do not apply Arsenal to irrigation ditches, and do not allow runoff to cropland. Arsenal is corrosive to mild steel, brass, and copper.

Many of the granular or pelleted materials are organic herbicides formulated on sodium borate or borate-chlorate granules. They are applied dry, which makes them convenient for spot treatment or application on small areas.

Care should be taken not to apply bromacil, hexazinone, and tebuthiuron too close to trees and shrubs. Because of root uptake, these herbicides can be lethal to desirable species. Oaks are especially sensitive.

Organic Herbicides for Short-Term Control

1. **Amitrole** (Amizol, Amitrol-T) is a translocated herbicide that is especially effective on poison ivy and Canada thistle and on perennial grasses such as quackgrass. Amizol is a 90 percent soluble powder that is applied at a rate of 2 to 5 pounds per acre in 50 to 100 gallons of water. Amitrole plus ammonium thiocyanate is available as Amitrol-T in a 2-pound-per-gallon liquid. The application rate is 1 to 4 gallons per acre. Amizol and Amitrol-T are restricted-use pesticides. (Amitrole plus simazine is available as Amizine; see Organic Herbicides for Long-Term Control, above).

2. **Dalapon** (Dowpon-M, Dalapon 85) is a foliage-applied, translocated grass herbicide. It is available with TCA (Dowpon-C, Revenge) for longer residual control. The rate is 10 to 15 pounds per acre of the 85 percent soluble powder. Use of a surfactant improves control. Perennial grass may require more than one application.

3. **TCA** (Sodium-TCA Weed Killer) is a root-absorbed grass herbicide that remains active in the soil longer than dalapon. It is a 90 percent soluble powder used at 50 to 150 pounds per acre.

4. **MSMA** is available as Daconate, a 6-pound-per-gallon liquid with a surfactant included. It is used for perennial grass control at 0.5 to 1.5 gallons per acre. More than one application may be necessary.

5. **DSMA** is available either as a liquid or as a soluble powder. It can be used for spot treatment of johnsongrass. The rate is 3 to 9 pounds per acre of the soluble powder or 1 to 2 gallons per acre of the liquid.

6. **Paraquat** (Gramoxone) is a contact herbicide with no residual activity. Gramoxone Super is a formulation containing 1.5 pounds active ingredient per gallon, labeled at 2.5 to 5 pints per acre. Gramoxone Extra is a 2.5-pound-per-gallon formulation, labeled at 2 to 3 pints per acre. The volume of water should be adjusted for the amount of vegetation. Paraquat requires the addition of a surfactant. Paraquat is restricted to use by certified applicators.

7. **Glyphosate** (Roundup) is a 4-pound-per-gallon translocated herbicide that is nonpersistent. Unlike paraquat, it will translocate to control perennial weeds. The rate is 1 to 5 quarts per acre.

HERBICIDES FOR BROADLEAF WEED AND BRUSH CONTROL

1. **Dicamba** (Banvel) is available as a 4-pound-per-gallon formulation. The rate is 1 to 4 quarts per acre. Formulated mixtures with other herbicides are also available. Banvel presents a drift hazard to nearby soybeans, tomatoes, and other broadleaf plants.

2. **Picloram** (Tordon) is a broadleaf weed and woody plant herbicide that does not affect grass species. Picloram is formulated as liquid Tordon K (2 lb/gal); Tordon 101, 101R, and RTU herbicides (mixtures of picloram and 2,4-D); and Access herbicide (mixture of picloram and triclopyr esters). Tordon K and Tordon 101 herbicides are designed for application to foliage and stems, often in combination with triclopyr for maximum weed and brush control. Access herbicide is formulated for basal-bark applications. Picloram should not be used in areas of rapid permeability and high water table. Picloram is restricted for use by certified applicators only.

3. **Fenac** can be used for the control of deep-rooted, perennial broadleaf weeds. It is formulated as a 1.5-pound-per-gallon liquid. The application rate is 2 to 15 gallons per acre.

4. **2,4-D** is a broadleaf herbicide with little soil activity. Amine formulations present less hazard to nearby sensitive plants than esters because amines volatilize at higher temperatures. The common formulation is a 4-pound-per-gallon liquid. Mixtures of 2,4-D and dalapon are often used for short-term control of both broadleaf and grass weeds.

5. **Dichlorprop** or **2,4-DP** (Weedone 2,4-DP) gives better control of some woody plants than 2,4-D. Commercial mixtures of dichlorprop plus 2,4-D (Weedone 170 and Weedone CB) are available for broader-spectrum control.

6. **Bromacil** (Hyvar X or Hyvar X-L) is a 2-pound-per-gallon liquid for basal spraying of brush. A 10 percent pellet (HABCO-10B) is also available.

7. **Fosamine** (Krenite) is available as two different 4-pound-per-gallon formulations. When Krenite is applied within two months of autumn leaf discoloration, no symptoms are evident until the following spring, when the plants fail to refoliate. Because Krenite does not translocate, it can be used for chemical trimming. The rate is 1.34 to 3 gallons per acre.

8. **Triclopyr** (Garlon 4, Garlon 3A) is available in 3- or 4-pound-per-gallon formulations, in a formulated mix with 2,4-D (Crossbow), and in a mix with picloram (Access) for basal-bark applications. Triclopyr is a broad-spectrum broadleaf and brush herbicide with no activity in grasses when used at recommended rates. It can be applied in foliar, basal-bark, or cut-surface applications to control many trees, brush species, and herbaceous broadleaf plants.

9. **Isoxaben** (Gallery 75DF) is a 75 percent dry flowable to be applied preemergence for broadleaf weed control at rates from 0.66 to 1.33 pounds per acre. Gallery should be applied in late summer to early fall or in early spring prior to the germination of target species.

Long-Term Residual Control: Spray Applications

Many of these chemicals are wettable powders (WPs) and will require thorough agitation before application. A rate range is given to account for different soils and the different types of weeds to be controlled. Initial applications are often made at the higher rate, with subsequent treatments at the lower rate.

It is not always prudent to try to achieve control for more than one season with one application. Instead, use a lower rate and reapply annually.

	Rate of formulation per acre		
Herbicide	Annuals	Shallow perennials	Deep perennials
AAtrex (80W)	6 to 12.5 lb	12.5 to 25 lb	25 to 50 lb
Amizine (60W)	6 lb	12 lb	20 lb
Arsenal 2S	2 to 4 pt	1 to 6 pt	4 to 6 pt
Asulox (3.3 lb/gal)	1 to 2 gal	1 to 2 gal	...
Casoron (50W)	8 to 12 lb	12 to 25 lb	25 to 40 lb
Hyvar X (80W)	3 to 6 lb	7 to 12 lb	15 to 30 lb
Hyvar X-L (2 lb/gal)	1.5 to 3 gal	3 to 6 gal	6 to 12 gal
Karmex (80W or 80DF)	5 to 20 lb	20 to 40 lb	20 to 60 lb
Krovar I (80W or 80DF) . . .	4 to 6 lb	7 to 18 lb	19 to 40 lb
Oust (75WDG)[a]	3 to 5 oz	6 to 12 oz	6 to 12 oz
Pramitol 25E (2 lb/gal) . .	5 to 7.5 gal	7.5 to 20 gal	20 to 30 gal
Princep (80W)	6 to 12.5 lb	12.5 to 25 lb	12.5 to 22.5 lb
Sodium chlorate	300 to 500 lb	500 to 750 lb	750 to 1,300 lb
Spike (80W)	5 to 7.5 lb	2.5 to 5 lb	3.75 to 7.5 lb
Telar (75 WDG)[a]	0.25 to 1 oz	1 to 3 oz	...
Velpar (90WSP)	2 to 5 lb	6 to 12 lb	...
Velpar L or RP (2 lb/gal WDL)	1 to 2.5 lb	3 to 6 lb	...

[a]Note that the rate of formulation is in ounces per acre.

Long-Term Residual Control: Granular or Pellet Application

Granules are convenient to use for spot treatments or applications to small areas. Many granules are made with a sodium chlorate-borate base.

Herbicide	Pounds per 1,000 sq ft
Arsenal 5G	4.6
Atratol 8P	2.5 to 10
Casoron-10P	5 to 10
Chlorea-3	10 to 20
Concentrated Borascu	40 to 60
Pramitol 5P	5 to 20
Princep 4G	5.75 to 10.35
Sodium chlorate-borate	30 to 40
Sodium chlorate-modified	20 to 40
Spike 5G	0.45 to 2.75
Spike 20P	0.1 to 0.7
Spike 40P	0.05 to 0.35
Urox-'HX'	7 to 14

BROADLEAF WEEDS

Broadleaf weeds are often best controlled with foliar applications. Deep-rooted perennials can usually be controlled best when they are at the early bud to early bloom stage. Some of the herbicides listed below can move through the air and damage nearby desirable trees, shrubs, and broadleaf plants. Some of the herbicides are mobile in the soil and can damage desirable broadleaves if applied to the soil near their roots.

	Rate of formulation per acre	
	Annual and shallow perennials	Deep-rooted perennials
Banvel (dicamba)	0.5 to 1 qt	1 to 4 qt
Crossbow (triclopyr + 2,4-D)	1 to 2 qt	2 qt
Fenac	2 to 5 gal	10 to 15 gal
Roundup (glyphosate)	0.5 to 3 qt	3 to 5 qt
Tordon 101 (picloram + 2,4D)	2 to 3 qt	1 to 3 gal
Tordon K (picloram)	0.5 to 2 qt	2 to 4 qt
2,4-D	1 to 2 qt	2 to 4 qt
Garlon 4 (triclopyr)	1 to 2 qt	2 to 4 qt
Garlon 3A (triclopyr)	2 to 3 qt	3 to 6 qt

UNDESIRABLE WOODY PLANTS

Most of the herbicides used to control woody plants are applied to the foliage, but many of them can also be applied as basal-bark treatments if the woody plants have stems that are smaller than 5 inches in diameter or as cut-surface (frilled) treatments if the plants are larger. Basal-bark treatments are usually applied in fuel oil. Application can be made throughout the year, even during the dormant season. Cut-surface treatments can also be made throughout the year, but the herbicides should be applied to the cut surface within 2 to 3 hours of cutting. Foliar treatments are usually applied in the spring as soon as the leaves of brush or trees have fully expanded.

Herbicide	Method of application	Rate of formulation
Access (picloram + triclopyr).	basal-bark	1 to 2 gal/100 gal spray mixture*
Arsenal 2S (imazapyr)	foliar	4 to 6 pt
Banvel (4 lb/gal dicamba)	foliar	2 to 4 qt/A
Crossbow (triclopyr + 2,4-D)	foliar	4 to 6 qt/A
Escort (metsulfuron)	foliar	1/3 to 2 oz/A
Garlon 3A (44.4 percent triclopyr) . .	foliar or cut-surface	2 to 3 gal/A
Garlon 4 (61.6 percent triclopyr) . .	foliar or basal-bark	4 to 8 qt/A*
Krenite (4 lb/gal)	foliar	1.5 to 3 gal/A
Roundup (glyphosate)	foliar	2 to 5 qt/A
	spot treatment	1 to 2 percent solution
Tordon 101 (picloram + 2,4-D)	foliar or cut-surface	1 to 4 gal/A
Weedone 170 (2,4-D + dicloprop) . . .	foliar	4 to 6 qt/ 100 gal spray
	basal-bark or cut-surface	3 to 4 gal/ 100 gal spray
2,4-D ester	foliar or basal-bark	2 to 4 qt/A

*20 to 30 percent in carrier for low-volume application.

WEEDY GRASS CONTROL

Weedy grasses can be controlled with the herbicides listed below. The use of a spreader-sticker (surfactant) is labeled for some of these herbicides.

Herbicide	Rate of formulation per acre	
	Annuals	Perennials
Asulox	1 to 2 gal	1 to 2 gal
Cytrol, Amitrol-T	1 gal	2 to 3 gal
Daconate	2 to 3 qt	3 to 5 qt
Dowpon	5 to 10 lb	10 to 30 lb
MSMA, DSMA	1 to 2 qt	2 to 4 qt
Roundup	.38 to 2 qt	1 to 5 qt
Sodium-TCA	20 to 50 lb	100 to 150 lb

CONTACT WEED CONTROL

Contact herbicides kill only the plant tissue with which they come in contact; therefore, adequate spray volume is needed for thorough coverage of the foliage. A surfactant is often required by the herbicide label to help improve foliar coverage.

Herbicide	Rate per acre
Herbicidal naphtha	20 to 50 gal
Gramoxone Super	1 to 3 qt
Gramoxone Extra	2/3 to 1 2/3 qt

COMMENTS

Whenever possible, use desirable plants to compete with and replace undesirable plants. For some areas, mechanical control may be the most practical and appropriate method.

Availability, formulations, trade names, and federal clearance for the use of herbicides change from time to time. Always refer to the most recent product label for precautions, directions for use, and rates of application. Use herbicides appropriately to avoid injury to yourself and others, to desirable nontarget vegetation, and to the environment.

Brush Control in Illinois

D. Anderson and M. McGlamery

Brush control is used to improve and maintain pastures, recreational areas, fencerows, drainage ditch banks, rights-of-way, and other noncrop areas. Brush can be controlled by mechanical means such as cutting or digging, by herbicide treatments, or by a combination of mechanical and chemical control measures that remove the plant and prevent resprouting.

Mechanical control is costly and time-consuming. Retreatment may be required for complete control because resprouting often occurs when herbicides are not used. Herbicides are generally less time-consuming and labor-intensive than are mechanical control methods, because complete control can be achieved with one treatment if the herbicide program is carefully planned. However, chemical control alone does not remove the dead plants.

Some brush herbicides are selective; they leave grasses unharmed while controlling brush and broadleaf weeds. These herbicides can injure desirable broadleaf plants if they are allowed to drift, run off, or leach out of the treatment area. Nonselective herbicides are also potentially hazardous to desirable plants, but they can be used as spot treatments to control brush species if they are applied carefully so that they do not move from the specific treatment area.

Some herbicides used for brush control have grazing and harvest restrictions. Some cannot be applied to aquatic areas, irrigation or drainage ditches, or to areas where they could run off or leach into those water systems. Be sure to follow label restrictions and recommendations closely and to make applications carefully.

METHODS OF APPLICATION

Various methods can be used to get the herbicide into the target plant. Table 1 lists common brush herbicides and indicates the areas for which they are labeled, the appropriate application methods, and the type of brush they control. Tables 2 through 5 describe the susceptibility of common brush species to various herbicides applied by foliar, basal-bark, cut-surface, or soil application methods. The information in these tables was taken from herbicide labels and from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture.

Foliar treatments are most effective when applied to fully developed plant foliage during late spring or early summer. Most herbicides can be applied throughout the growing season although translocation may be restricted by adverse temperature or moisture stress. Good foliar coverage is necessary for control, and some products should be applied so that they also drench the stem.

The effectiveness of some foliar herbicides can be reduced if rainfall occurs on the day of treatment. Foliar treatments should usually be applied only to shrubs or small trees. Large trees should be treated by another method to improve control and reduce drift potential.

When making foliar applications, take precautions against particle drift from the spray to nearby susceptible plants. Do not spray when the wind velocity is greater than 5 miles per hour or when the wind is blowing toward sensitive crops or ornamentals. Reduce the spray pressure and use nozzles with large orifices to apply herbicides that do not require coverage with fine spray droplets to achieve good control. Drift-reducing spray additives and equipment are available, but to achieve good control and to ensure minimum drift, you must adhere closely to all label precautions and directions. Certain formulations volatilize and should not be used when drift prevention is crucial. Some herbicide labels list sensitive species and areas that must be protected from drift and direct application.

Basal-bark treatments are oil-soluble herbicides applied in a carrier of diesel oil or kerosene; they are applied to the lower 12 to 18 inches of brush plants that are less than 4 to 5 inches in diameter. With high-volume, basal-bark applications of 1 to 5 percent herbicide, the spray should thoroughly drench the stem, the groundline, and all exposed roots. With low-volume applications of 20 to 30 percent herbicide, wet the stem to the point of glistening but not runoff. The herbicides commonly used for basal-bark treatments can cause injury if the vapor or particles drift to desirable crops or ornamentals. Although basal-bark treatments can be made throughout the year, applications made during the dormant season are less likely to result in drift injury. Do not apply when snow prevents treating the bark to the groundline. Some species, such as maples, should not be treated during heavy sap flow. Basal-bark treatments are more labor-intensive than foliar treatments, but they are useful as a technique to selectively remove undesirable species from stands of desirable trees. They are also useful where brush density is low to moderate.

Cut-surface treatments are more effective than basal-bark treatments on thick-barked species and on plants that are greater than 5 inches in diameter. The herbicide is applied to the stump of a cut plant or to frills or notches cut around the plant to a depth of at least 1/2 inch into the sapwood. Continuous cuts rather than spaced notches or frills may be more effective for difficult-to-control species. Special injection equipment can be used to cut into the plant and to apply the herbicide in one operation. The herbicide should be applied to the cut surface before the exposed plant tissue dries, which is usually within 2 or 3 hours after cutting. When treating cut stumps, thoroughly drench the cambium area next to the bark. Cut-surface applications can be made during any season of the year, but application during the dormant season minimizes the potential for drift injury.

Soil treatments can be made with certain herbicides that move through the soil to the root zone and then translocate upward to kill the plant. Soil treatments are applied within the dripline of the target species either as sprays or in dry form as granules, beads, or pellets. Apply these herbicides carefully to minimize injury to nearby desirable species. Nontarget injury can result if the herbicide moves laterally in the soil or in treated areas where the root zones of desirable and target species overlap.

Most soil treatments should be made between the last hard frost in the spring and the first hard frost in autumn. Soil treatments should not be applied to frozen ground. Many soil-applied herbicides remain active in the soil for several months; for this reason, do not use soil-applied herbicides where they might run off into water sources or leach into groundwater.

BRUSH HERBICIDES

Phenoxy herbicides used for brush control are 2,4-D and dichlorprop (2,4-DP). These herbicides are sold under several different trade names. 2,4-D is labeled for brush control in pastures, drainage ditch banks, rights-of-way, and noncrop areas. Dichlorprop is labeled for use on rights-of-way and noncrop areas. Other herbicides are sometimes combined with 2,4-D or dichlorprop to broaden the spectrum of susceptible plants.

The phenoxy herbicides are readily absorbed by plant foliage. Oil-soluble formulations (esters or oil-soluble amines) applied in kerosene or diesel oil carriers will penetrate the bark of most woody plants. The esters are usually more effective than the amines for treating brush and trees with foliar or basal-bark sprays. Amines are preferable for injection and cut-surface treatments.

A minute amount of phenoxy herbicide may cause injury to highly susceptible nontarget plants such as tomatoes, grapes, cucumber, and ornamentals--whether the method of application is foliar, basal-bark, or cut-surface. Generally a foliar treatment is potentially more hazardous than the other methods because it requires a greater volume of herbicide spray solution. The vapor from a phenoxy treatment may travel up to 1/2 mile. To reduce vapor drift, use an amine rather than an ester formulation when possible. Do not use an ester when the temperature on the day of treatment might exceed 85°F. Do not treat in the vicinity of sensitive nontarget plants. Do not apply phenoxy herbicides to water intended for domestic use or irrigation.

If possible, do not use phenoxy spray equipment to apply other pesticides to phenoxy-susceptible plants. Some residue may remain even after thorough cleaning. Follow all use restrictions listed on the herbicide label.

Banvel (dicamba) is a selective, translocated herbicide that can be absorbed through either the roots or the aboveground portions of plants. Banvel is used for foliar, cut-surface, or basal-bark treatments. For multiflora rose control, a spot concentrate application of Banvel to the soil can be made. Spray the soil as closely as possible to the crown root (within six to eight inches of the crown). Foliar sprays can be applied with ground or aerial equipment, but aerial application should not be made in the vicinity of sensitive plants. The spectrum of species controlled with Banvel can be broadened by the addition of 2,4-D as recommended on the label.

Like the phenoxys, Banvel volatilizes readily and is effective in small amounts. Prevent drift to sensitive feed and food crops, ornamentals, and conifers. Do not apply Banvel when the temperature is expected to exceed 85°F within several days of the application. Because Banvel is root absorbed, do not treat areas where the herbicide may leach or run off and contact the roots of desirable plants.

The label restricts the use of Banvel near soybeans in certain stages of growth. Grazing and harvest intervals are stated on the label. Study the label carefully before applying Banvel. If possible, do not use equipment used to spray Banvel to apply other pesticides to Banvel-susceptible plants because some residue may remain even after thorough cleaning.

Tordon (picloram) is a selective, translocated herbicide that is absorbed by plant roots and foliage. Formulations are available for foliar, basal-bark, soil, or cut-surface applications. Mixtures with phenoxy herbicides (Tordon 101, 101R, RTU) are available to give broader-spectrum weed control.

Applications can be made to either foliage or soil. With soil treatments, control is enhanced as rainfall moves the herbicide into the root zone. Broadcast foliar or soil treatments are recommended for dense brush. Spot treatments can be made to individual plants or scattered stands of brush. Tordon products can be mixed with Garlon herbicide to provide a broad spectrum of broadleaf weed and woody plant control.

A low concentration can cause extensive damage to susceptible species. Do not apply where runoff or leaching could move the herbicide into the root zone of susceptible nontarget plants, such as conifers or broadleaf ornamentals and crops. Prevent picloram from drifting into water containments and areas where desirable plants are growing. Drift injury to nontarget species is much less likely to result in injury if treatment is made during the dormant season.

Tordon K and Tordon 101 are restricted-use herbicides (RUP) that can be applied only by certified private or commercial applicators. Tordon RTU and 101R, which are premixed and labeled for cut-surface application only, are general-use herbicides.

Garlon (triclopyr) is a selective, translocated herbicide that can be applied as a foliar, basal-bark, or cut-surface treatment. Basal-bark treatments can be applied throughout the year. Compared to many brush herbicides, Garlon gives superior control of ash, oak, and certain root-sprouting species, such as sassafras and black locust. Commercial mixes of triclopyr plus 2,4-D (1:2) **(*Crossbow*)** or triclopyr plus picloram **(*Access*)** are available to control a broader spectrum of brush species. Take measures to prevent drift of Garlon formulations to susceptible ornamentals, crops, and conifers. The ester formulation is toxic to fish.

Trimec 352, Brush Killer 875, and other commercial mixtures of 2,4-D, mecoprop (MCPP), and dicamba are designed for foliar applications to give broad-spectrum brush control. A low concentration can damage susceptible species. Take precautions to prevent drift injury.

Escort (metsulfuron methyl) is labeled for the control of herbaceous and woody broadleaf plants. It is available as a 60 percent, dry flowable formulation labeled for foliar application at rates of 1/3 to 2 ounces per acre. For greatest effectiveness, the herbicide should be applied to completely cover the foliage and stems. The application can be made any time between one-half leaf stage in the spring until just before autumn leaf coloration. Plants are most susceptible when the application is made during warm, moist conditions and less susceptible when the weather is cool or dry. Woody species listed on the label include ash, cherry, elm, oak, red maple, and multiflora rose. Escort is most effective against broadleaf species, but at medium to high label rates it can suppress or severely injure certain grasses. Read the label carefully before making applications, especially in areas of desirable grasses.

Escort is labeled for use in noncrop areas, such as airports, roadsides, and utility, pipeline, and railroad rights-of-way. However, it should not be used on lawns, walks, driveways, tennis courts, or similar areas.

Escort injury symptoms (leaf discoloration) can take several weeks to appear, depending on environmental conditions. However, treated plants stop growth very soon after the application.

Do not apply the herbicide or drain or rinse application equipment near desirable plants, or on soil where roots of desirable plants may extend, or in locations where the herbicide may be moved into contact with the roots. Do not use spray equipment to apply products to desirable plants after it has been used to apply Escort because low rates of Escort can kill or severely injure desirable plants.

Krenite (fosamine) is a contact herbicide that is applied to the foliage of brush during the two-month period before autumn leaf coloration. No effects are seen until the following spring, when treated plants fail to refoliate and subsequently die. Pine species may respond during the season of treatment. Thorough coverage is required for complete control. By carefully directing the application, you can use Krenite to trim woody species without killing the entire plant. A surfactant can be used to improve control.

Krenite should not be applied to desirable plants, brush standing in water, or food crops. Krenite can be slightly corrosive to brass or copper spray equipment. Clean thoroughly after use to protect spray equipment.

Amitrole is a nonselective, translocated herbicide that is especially effective against poison ivy, poison oak, brambles, and honeysuckle. Amitrole can be used only where there is no possibility that residues will remain on food or feed crops (see Table 1). Amitrole is available in **Amizol**, which is a 90 percent, water-soluble powder and in **Amitrol-T**, which is a 2-pound-per-gallon soluble liquid. Amitrole is applied in foliar sprays. All leaves, stems, and suckers should be thoroughly wet to the groundline. The addition of a surfactant may improve control.

Because amitrole gives nonselective control, it should be directed away from desirable species if their loss would be detrimental. Keep amitrole out of aquatic areas if the water is intended for irrigation, drinking, fishing, or other domestic purposes. Keep livestock off treated areas. Amizol and Amitrol-T are restricted-use pesticides.

Roundup (glyphosate) is a nonselective, translocated herbicide, which can be used for spot treatments in areas where loss of ground cover is detrimental. Because plants absorb the herbicide through their foliage, glyphosate must be applied during the season of active growth. Flowering species should be treated when the plants are at or beyond the full-bloom stage of growth. Roundup has no soil activity. Prevent drift to foliage of nontarget species. Roundup can be tank-mixed with certain other herbicides to broaden the spectrum of control. See the label.

Arsenal (imazapyr) is a 2-pound-per-gallon formulation that is taken up by both foliage and roots and translocated to the meristems. It controls annual and perennial grasses and broadleaves and a broad spectrum of woody species. Arsenal can be applied preemergence or postemergence, but postemergence is the method of choice, especially to control perennials. Arsenal usually provides residual soil activity after a postemergent application. Prevent drift to desirable plants. Do not apply to irrigation ditches, and prevent runoff to crop land. Arsenal is corrosive to mild steel, brass, and copper.

Hyvar (bromacil) is a nonselective herbicide that is labeled for use on a wide spectrum of woody species. Two formulations are available: **Hyvar X**, which is an 80 percent wettable powder, and **Hyvar X-L**, which is a 2-pound-per-gallon water-soluble liquid formulation that stays in solution without continuous agitation. Both formulations are labeled for broadcast soil application on noncrop areas and rights-of-way. The recommended application time is just before emergence or during the period of active growth of the plants to be controlled. Hyvar X-L can be applied as a basal-bark or soil application in noncrop areas and rights-of-way and also in drainage ditches.

In addition to controlling brush species, Hyvar also controls herbaceous broadleaf and grass plants. Grass species are especially susceptible to injury. Spot treatments around the base of woody plants may be appropriate in areas where bare ground is undesirable.

Injury symptoms are generally slow to appear. Treated plants may not respond until the herbicide has been carried into the root zone by rainfall. In areas of dense growth, results will be improved if vegetation is removed before Hyvar is applied.

Do not apply to frozen soil or to brush standing in water. Do not use water from treated ditches for irrigation, and do not treat ditches that are adjacent to desirable plants.

Hyvar X is noncorrosive, nonflammable, and nonvolatile. Hyvar X-L is corrosive to aluminum and should not be applied with aluminum spray nozzles. Undiluted Hyvar X-L is combustible, so it must be kept away from heat and open flame. Do not smoke when handling this product.

Velpar (hexazinone) is a nonselective herbicide that is taken up by the roots and foliage of plants. Velpar is most effective when applied to the soil just before or soon after weed emergence. Velpar also has some contact activity if an appropriate surfactant is added to the spray mix. The recommended rate varies with soil type. Higher rates are recommended when treating hard-to-control species.

Avoid application of Velpar to the root zone or foliage of desirable plants. Spot treatment is necessary when bare soil is undesirable. Exceeding the concentration recommended on the label might clog nozzles and result in uneven distribution. Agitate the herbicide mixture for at least ten minutes until Velpar is thoroughly dissolved.

Spike (tebuthiuron) is a soil-applied nonselective herbicide that is absorbed by the roots of plants. It is available as an 85 percent dry flowable, an 80 percent wettable powder, in 1-pound water-soluble packets, or as pellets. Spike can be applied any time, except when the ground is frozen or the soil is saturated with moisture. To achieve the best results, apply the herbicide before or during active growth of target plants. Spike can be applied to the soil dry or with a water carrier. The dry application requires rainfall to wash the herbicide into the root zone.

Due to differences in susceptibility, different species require different rates of Spike. Consult the label for the correct rate of use for the plant species to be controlled. Spike can be applied broadcast or as an individual plant treatment, depending on the size, density, and location of the brush to be controlled.

The wettable powder formulation requires continuous agitation. Spike does not leach readily in the soil. Avoid application where runoff can wash the dry herbicide into nontarget areas. Prevent drift or direct application of Spike to the root zones of desirable plants.

Table 1. Label Clearances: Common Brush Herbicides

	Area				Application				Type of brush	
Brush herbicide	Pasture	Drainage-ditch bank	Right-of-way	Non-crop	Foliar-stem spray	Cut surface or injection	Basal bark[a]	Soil	Deciduous	Conifer
2,4-D amine	X	X	X	X	X	X	..	..	X	..
2,4-D ester	X	X	X	X	X	X	X	..	X	..
2,4-DP (dichlorprop)	..	..	X	X	X	X	X	..	X	..
Weedone 170 or Weedone CB (2,4-D + dichlorprop)	..	X	X	X	X	X	X	..	X	..
Banvel + 2,4-D	X	X	X	X	X	X	X[b]	..	X	X
Banvel 5G or 10G	X	X	X	X	..	..	..	X	X	X
Garlon 3A (triclopyr amine)	X	X	X	X	X	X	..	..	X	X
Garlon 4 (triclopyr ester)	X	X	X	X	X	..	X	..	X	X
Tordon K (picloram)	..	..	X	X	X	..	..	X	X	X
Tordon RTU or 101R	..	..	X	X	..	X	..	..	X	X
Tordon 101 Mixture (picloram + 2,4-D)	..	..	X	X	X	X	..	X	X	X
Access (esters of picloram + triclopyr)	..	..	X	X	..	..	X	..	X	X
Crossbow (triclopyr + 2,4-D)	X	X[c]	..	X	X	X	X	..	X	X
2,4-D + mecoprop + dicamba	..	X	X	X	X	..	..	..	X	..
Escort (metsulfuron)	..	..	X	X	X	..	..	..	X	..
Krenite	..	X	X	X	X	..	..	..	X	..
Amitrole + T	..	X	X	X	X	..	..	..	X	..
Roundup	d	X	X	X	X	..	..	..	X	..
Hyvar-X	..	X[e]	X	X	X	..	..	X	X	X
Velpar	..	..	X	X	X	..	..	X	X	..
Spike	X[f]	X[f]	X	X	..	..	..	X	X	X

[a]Oil-soluble forms only.
[b]Not for pasture use.
[c]Nonirrigation ditch banks only.
[d]Spot treatment only (10 percent of each acre).
[e]Soil application only.
[f]See specific formulation label.

Table 2. Foliar Herbicide Treatment: Susceptibility of Common Brush Species[a]

	2,4-D	Dichlorprop	Banvel	Tordon	Hyvar	Garlon	Escort	Amitrole	Roundup	Krenite
Ash, white (*Fraxinus americana*) . . .	R	R	S-R	R	S-R	S	S	S	S-I	I
Birch (*Betula* spp.)	S-I	S	S	S	S	S	...	...	S	S
Boxelder (*Acer negundo*)	S-I	I-R	...	S-I	S	S	...	...	S	...
Brambles--blackberry, raspberry, etc. (*Rubus* spp.)	I-R	I-R	S-I	S	S-I	S	...	S-I	S-I	S
Cherry, black and choke (*Prunus serotina and P. virginiana*)	I-R	I-R	S	S	S-I	S	S	S	S	I
Cottonwood, eastern (*Populus deltoides*)	S-R	R	R	S	S-I	S	...	...	...	S-I
Crabapple (*Pyrus ioensis*)	S-I	S	S	S	S	S-I	...	...	S	...
Elderberry (*Sambucus canadensis*)	S-I	I	S	S	S	S	...	...	S	...
Elms, American and slippery (*Ulmus* spp.)	I	S-I	I	S	S-I	S	S	...	S	S-I
Grapes, wild (*Vitis* spp.)	S-I	S-I	I-R	S	...	S	...	...	S	S-I
Greenbrier or catsbriar (*Smilax* spp.)	R	R	R	I-R	R	S-I	...	...	...	...
Hackberry (*Celtis* spp.)	I-R	I-R	I	S	S-I	S	...	...	S	...
Hawthorn (*Crataegus* spp.)	I-R	R	R	S-I	...	S	...	...	S	I
Hedge-apple or osage orange (*Maclura pomifera*)	I-R	R	I-R	S-I	...	S-I	...	...	...	...
Honeylocust (*Gleditsia triacanthos*)	I-R	I	S-I	S	S	S-I	...	...	S	...
Honeysuckle (*Lonicera* spp.)	S-I	S-I	I	S	S	S	...	S-I	S	...
Locust, black (*Robinia pseudoacacia*)	S-I	S-I	S	S	S	S	...	S	S	S
Maple, red (*Acer rubrum*)	R	R	I-R	S	S	S-I	S-I	...	S	...
Maple, silver (*Acer saccharinum*) . .	I-R	...	...	S	S	S	...	...	...	...
Maple, sugar (*Acer saccharum*)	I-R	...	...	S	...	S	...	...	S	...
Mulberry, red (*Morus rubra*)	I-R	I-R	S-I	S	...	S	...	...	...	...
Persimmon, eastern (*Diospyros virginiana*)	I	I-R	S-I	S	...	S-I	...	...	I	I
Plum, wild (*Prunus* spp.)	S-I	I	S-I	S	...	S-I	...	...	S	S-I
Poison ivy (*Rhus radicans*)	I	I	S	S	S	S	...	S	S	...
Redcedar, eastern (*Juniperus virginiana*)	R	R	I-R	S-I	S	R	...	...	S	S
Rose, multiflora (*Rosa multiflora*)	...	...	...	S	...	S	S	...	S	S-I
Sassafras (*Sassafras albidum*)	S-I	I	I	S	S	S	...	...	S	I
Sumac (*Rhus* spp.)	S	S	S	S	S-I	S	...	S	S	S
Tree-of-heaven (*Ailanthus altissima*)	S-I	S-I	S-I	S-I	S	S	...	...	S	S-I
Trumpetcreeper (*Campsis radicans*)	...	...	S-I	S-I	...	S-I	...	...	S-I	...
Virginia creeper (*Parthenocissus quinquefolia*)	S	S-I	...	S	...	S	...	...	S	...
Willow (*Salix* spp.)	S	S	S-I	S	S	S	...	...	S	I

[a]S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agricultural Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

Table 3. Basal-Bark Herbicide Treatment: Susceptibility of Common Brush Species[a]

	2,4-D	Dichlorprop	Banvel	Access	Hyvar	Garlon
Ash, white (*Fraxinus americana*)	R	R	S-I	S	S	S
Birch (*Betula* spp.)	S	...	...	S	S	S
Boxelder (*Acer negundo*)	S	S	S	S	S	S
Brambles--blackberry, raspberry, etc. (*Rubus* spp.)	I-R	S-R	S	S	S	S
Cherry, black and choke (*Prunus serotina and P. virginiana*)	S-R	S	S	S	S-I	S
Cottonwood, eastern (*Populus deltoides*) . . .	...	...	...	S	S	S
Crabapple (*Pyrus ioensis*)	S-I	S-I	S	S	S-I	...
Elderberry (*Sambucus canadensis*)	S-I	S	S	S	S	S
Elms, American and slippery (*Ulmus* spp.) . .	S-I	S-I	S	S	S-I	S
Grapes, wild (*Vitis* spp.)	...	...	...	S	...	S
Greenbrier or catsbriar (*Smilax* spp.)	I	...	R	I-R	R	...
Hackberry (*Celtis* spp.)	S	S	...	S	S	S
Hawthorn (*Crataegus* spp.)	I	S-R	S-R	S	S	S
Hedge-apple or osage orange (*Maclura pomifera*)	I	R	...	S	I	...
Honeylocust (*Gleditsia triacanthos*)	I	I	...	S	S	S
Honeysuckle (*Lonicera* spp.)	S	S	S	S	I-R	S
Locust, black (*Robinia pseudoacacia*)	I	I-R	S-I	S	S	S
Maple, red (*Acer rubrum*)	R	R	S	S	S	S-I
Maple, silver (*Acer saccharinum*)	I	...	...	S	S	S
Maple, sugar (*Acer saccharum*)	...	...	...	S	...	S
Mulberry, red (*Morus rubra*)	I-R	I-R	S	S	I	S
Persimmon, eastern (*Diospyros virginiana*) . .	I-R	R	S	S	I	S
Plum, wild (*Prunus* spp.)	S-I	S-I	S	S	S	...
Poison ivy (*Rhus radicans*)	I	...	...	S	S	S
Redcedar, eastern (*Juniperus virginiana*) . .	R	R	S-I	S	S	R
Rose, multiflora (*Rosa multiflora*)	...	...	...	S	...	S
Sassafras (*Sassafras albidum*)	S-I	S-R	S	S	I	S
Sumac (*Rhus* spp.)	R	R	S	S	S	S
Tree-of-heaven (*Ailanthus altissima*)	S-R	S-I	S	S	S	S
Trumpetcreeper (*Campsis radicans*)	...	...	...	...	...	S-I
Virginia creeper (*Parthenocissus quinquefolia*)	...	...	...	...	R	...
Willow (*Salix* spp.)	S	S	...	S	S	S

[a]S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

Table 4. Injection and Cut-Surface Treatment: Susceptibility of Common Brush Species[a]

	2,4-D	Dichlorprop	Garlon 3A	Banvel	Tordon + 2,4-D
Ash, white (*Fraxinus americana*)	I	...	S	S	S
Birch (*Betula* spp.)	...	S-I	S	S	S
Boxelder (*Acer negundo*)	...	...	R	...	S-I
Brambles--blackberry, raspberry, etc. (*Rubus* spp.)	...	S	S	...	...
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	...	S-I	S	...	S
Cottonwood, eastern (*Populus deltoides*)	S-I	...	S	...	S
Crabapple (*Pyrus ioensis*)	...	...	S	...	...
Elderberry (*Sambucus canadensis*)	...	...	S	...	S
Elms, American and slippery (*Ulmus* spp.)	S-I	...	S	...	S-I
Grapes, wild (*Vitis* spp.)	S	...	S	...	S
Greenbrier or catsbriar (*Smilax* spp.)	...	...	...	...	...
Hackberry (*Celtis* spp.)	S	...	S	...	S
Hawthorn (*Crataegus* spp.)	R	...	S	...	S-I
Hedge-apple or osage orange (*Maclura pomifera*)	S-I	...	...	...	S-I
Honeylocust (*Gleditsia triacanthos*)	...	...	S-I	...	S
Honeysuckle (*Lonicera* spp.)	...	S-I	R	...	S
Locust, black (*Robinia pseudoacacia*)	S	S-I	S	...	S
Maple, red (*Acer rubrum*)	I-R	...	S	S-I	S
Maple, silver (*Acer saccharinum*)	...	...	...	...	S
Maple, sugar (*Acer saccharum*)	R	...	...	S	S
Mulberry, red (*Morus rubra*)	...	...	S	...	S
Persimmon, eastern (*Diospyros virginiana*)	I	...	S	S	S-I
Plum, wild (*Prunus* spp.)	...	...	...	...	...
Poison ivy (*Rhus radicans*)	...	S-I	S	...	S
Redcedar, eastern (*Juniperus virginiana*)	R	...	R	S-I	I
Rose, multiflora (*Rosa multiflora*)	...	...	S	...	S
Sassafras (*Sassafras albidum*)	...	...	S	...	S
Sumac (*Rhus* spp.)	...	...	S	...	S
Tree-of-heaven (*Ailanthus altissima*)	...	...	S	...	S-I
Trumpetcreeper (*Campsis radicans*)	...	...	...	...	S
Virginia creeper (*Parthenocissus quinquefolia*)	...	...	...	...	...
Willow (*Salix* spp.)	S	S-I	S	...	S

[a]S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

Table 5. Soil Herbicide Treatment: Susceptibility of Common Brush Species[a]

	Tordon	Hyvar	Velpar	Spike
Ash, white (*Fraxinus americana*)	R	S	...	I
Birch (*Betula* spp.)	S	S	...	S
Boxelder (*Acer negundo*)	S	S	...	S
Brambles--blackberry, raspberry, etc. (*Rubus* spp.)	S-I	S	...	I
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	S	S-I	...	I
Cottonwood, eastern (*Populus deltoides*)	S	...	...	S
Crabapple (*Pyrus ioensis*)	S	I	...	...
Elderberry (*Sambucus canadensis*)	S-I	S	...	...
Elms, American and slippery (*Ulmus* spp.)	S	S	...	S
Grapes, wild (*Vitis* spp.)	S-I	...	...	...
Greenbrier or catsbriar (*Smilax* spp.)	R	R	...	I
Hackberry (*Celtis* spp.)	S	S	...	S
Hawthorn (*Crataegus* spp.)	S	S-R	S-I	S
Hedge-apple or osage orange (*Maclura pomifera*)	S-I	R	...	...
Honeylocust (*Gleditsia triacanthos*)	S	S	...	I
Honeysuckle (*Lonicera* spp.)	S	I-R	...	S
Locust, black (*Robinia pseudoacacia*)	S	S	...	S
Maple, red (*Acer rubrum*)	S	S	...	S-I
Maple, silver (*Acer saccharinum*)	I	S	...	I
Maple, sugar (*Acer saccharum*)	S	...	...	S
Mulberry, red (*Morus rubra*)	S	I	...	I
Persimmon, eastern (*Diospyros virginiana*)	S	I	...	I-R
Plum, wild (*Prunus* spp.)	S	S	...	S
Poison ivy (*Rhus radicans*)	S	S	...	I-R
Redcedar, eastern (*Juniperus virginiana*)	S-I	S	...	S
Rose, multiflora (*Rosa multiflora*)	S	...	...	S
Sassafras (*Sassafras albidum*)	S	I	...	I-R
Sumac (*Rhus* spp.)	S	S	S-I	S
Tree-of-heaven (*Ailanthus altissima*)	S	S	...	S
Trumpetcreeper (*Campsis radicans*)	S	...	S-I	S
Virginia creeper (*Parthenocissus quinquefolia*)	S	R	...	S
Willow (*Salix* spp.)	S	S	S-I	S

[a]S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant. Data are from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture and from herbicide companies.

Chemical Control of Some Aquatic Plants

R. Hiltibran
(revised by D. Anderson)

Group and species	Herbicide	Rate of application	Remarks
EMERSED PLANTS			
Arrowhead (*Sagittaria* spp.)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb/440 sq ft	Spread on water
	ester (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	amine (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	diquat cation (2 lb/gal)	1/4 cup/gal	Wet foliage
Bulrush (*Scirpus actus* Muhl.)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb/440 sq ft	Spread on water
	ester (4 lb/gal)	1/2 cup/2 gal	Wet stems
	diquat cation (2 lb/gal)	2 tbsp/3 gal and 1 tsp nonionic wetting agent	Wet foliage to point of run-off
	dichlobenil (aquatic granules 10%)	40 lb/A	Apply in March to exposed bottom soil
Cattail (*Typha* spp.)	Use one of the following:		
	dalapon	4 oz/gal and 3 caps detergent	Wet foliage
	amitrole	2 oz/gal and 3 caps detergent	Wet foliage
	2,4-D ester (4 lb/gal)	1/2 cup/gal and 3 caps detergent	Wet foliage
	diquat cation (2 lb/gal)	2 tbsp/3 gal and 1 tsp nonionic wetting agent	Wet foliage
	glyphosate Rodeo (4 lb/gal) Pondmaster (4 lb/gal)*	2 tbsp/1 gal plus 1/2 to 1 tbsp of non-ionic surfactant	Wet foliage of actively growing plants at bloom stage or later

*Pondmaster is being marketed for farm use.

Group and species	Herbicide	Rate of application	Remarks
Creeping water primrose (*Jussiaea repens L.* var. *glabrescens* Ktze.)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb/440 sq ft	Spread on water
	ester (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	amine (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	diquat cation (2 lb/gal)	1/4 cup/2 gal	Wet foliage
Phragmites (*Phragmites australis*)	glyphosate Rodeo (4 lb/gal) Pondmaster (4 lb/gal)	2 tbsp/1 gal plus 1/2 to 1 tbsp of non-ionic surfactant	Wet foliage at full bloom stage or during autumn. Repeat treatments required.
Spatterdock (*Nuphar advena* (Ait.) Ait. f.)	dichlobenil (aquatic granules 10%)	60 lb/A	Spread on water
	glyphosate Rodeo (4 lb/gal) Pondmaster (4 lb/gal)	2 tbsp/1 gal plus 1/2 to 1 tbsp of nonionic surfactant	Wet foliage at full bloom stage during summer or fall.
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Waterwillow (*Justicia americana* (L.) Vahl)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb/440 sq ft	Spread on water
	ester (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	amine (4 lb/gal)	1/4 cup/2 gal	Wet foliage
	diquat cation (2 lb/gal)	1/4 cup/2 gal	Wet foliage
SUBMERSED PLANTS WITH ALTERNATE LEAF ATTACHMENT			
Curlyleaf pondweed (*Potamogeton crispus* L.)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below surface
	diquat cation (2 lb/gal)	0.5 ppm or 1 gal/surface A	Same as previous
	dichlobenil (aquatic granules 10%)	80 lb/A	Preemergent application
	fenac	See manufacturer's directions	Must be applied to exposed pond bottom

Group and species	Herbicide	Rate of application	Remarks
Curlyleaf pondweed (*continued*)	diquat cation/copper-triethanolamine complex	0.25 ppm diquat cation plus an equal volume of copper-triethanolamine complex	Apply on or below water surface
	simazine (80WP)	1 to 2 ppm	Apply to total water volume
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Leafy pondweed (*P. foliosus* Raf.)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb/gal)	0.5 ppm or 1 gal/surface A	Same as above
	dichlobenil (aquatic granules 10%)	40 lb/A	Preemergent application*
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom
	simazine (80WP)	1 to 2 ppm	Apply to total water volume
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Sago pondweed (*P. pectinatus* L.)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb/gal)	0.5 ppm	Same as above
	dichlobenil (aquatic granules 10%)	80 lb/A	Preemergent application
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom
	simazine (80WP)	1 to 2 ppm	Apply to total water volume
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface

*The preemergent aquatic herbicides have not given satisfactory season-long control of leafy pondweed.

Group and species	Herbicide	Rate of application	Remarks
Small pondweed (*P. pusillus* L.)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb/gal)	0.5ppm	Same as above
	dichlobenil (aquatic granules 10%)	80 lb/A	Preemergent application
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed bottom
	simazine (80WP)	1 to 2 ppm	Apply to total water volume
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Waterstargrass (*Heteranthera dubia* (Jacq.) MacM.)	Use one of the following:		
	diquat cation (2 lb/gal)	1 ppm or 2 gal/ surface A	Apply on or below water surface
	endothall (potassium salt, 4.23 lb/gal or 10% G)	5 ppm	Same as above
SUBMERSED AQUATIC PLANTS WITH OPPOSITE LEAF ATTACHMENT			
White buttercup (*Ranunculus trichophyllus* Chaix)	diquat cation (2 lb/gal)	0.5 ppm	Apply below water surface
Slender naiad (*Najas flexilis* (*Willd.*) Rostk. & Schmidt)	Use one of the following:		
	copper-ethylene-diamine complex*	0.5-1.0 ppm (copper)	Apply below water surface
	diquat cation (2 lb/gal)	1 ppm or 1.5 gal/ surface A	Apply below water surface
	diquat cation/copper-triethanolamine complex	0.5 ppm diquat cation plus an equal volume of copper-triethanolamine complex	Apply on or below water surface
	endothall (potassium salt, 4.23 lb/gal or 10% G)	3 ppm (total or large-scale application) 4 ppm (marginal application)	Same as above

*Sold under the trade name of Komeen by the Sandoz Corporation.

Group and species	Herbicide	Rate of application	Remarks
Slender naiad (*continued*)	dichlobenil (aquatic granules 10%)	80 lb/A	Preemergent application
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Southern naiad (*N. guadalupensis* (*Spreng.*) *Magnus*)	Use one of the following:		
	copper-ethylene-diamine complex*	0.5-1.0 ppm (copper)	Apply below water surface
	diquat cation (2 lb/gal)	1 ppm or 1.5 gal/surface A	Apply below water surface
	diquat cation/copper triethanolamine	0.5 ppm diquat cation plus an equal volume of copper-triethanolamine complex	Apply on or below water surface
	endothall (potassium salt, 4.23 lb/gal or 10% G)	3 ppm (total or large-scale application) 4 ppm (marginal application)	Same as above
	dichlobenil (aquatic granules (10%)	80 lb/A	Preemergent application
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
SUBMERSED AQUATIC PLANTS WITH WHORLED LEAF ATTACHMENT			
Common coontail (*Ceratophyllum demersum L.*)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal or 10% G)	2 ppm	Spread on water
	2,4-D ester (20% G)	2 ppm	Spread on water
	diquat cation (2 lb/gal)	1 ppm, or 2 gal/surface A	Apply below water surface
	diquat cation/copper-triethanolamine complex	0.5 ppm diquat cation plus an equal volume of copper-triethanolamine complex	Apply on or below water surface
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface

*Sold under the trade name of Komeen by Sandoz Corporation.

Group and species	Herbicide	Rate of application	Remarks
Elodea (*Elodea canadensis* Michx.)	Use one of the following:		
	copper-ethylenediamine complex*	0.5-1.0 ppm (copper)	Apply below water surface
	diquat cation (2 lb/gal)	1 ppm, or 2 gal/ surface A	Apply below water surface
	diquat cation/copper-triethanolamine complex	0.5 ppm diquat cation plus an equal volume of copper-triethanolamine complex	Apply on or below water surface
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Watermilfoil (*Myriophyllum* spp.)	Use one of the following:		
	2,4-D ester (20% G)	2 ppm	Spread on water
	endothall (potassium salt, 4.23 lb/gal	3 ppm	Apply below water surface
	or 10% G)	3 ppm of 10% G	Spread on water
	diquat cation (2 lb/gal)	1 ppm	Apply below water surface
	dichlobenil (aquatic granules 10%)	100-150 lb/A	Spread on water
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
FLOATING-LEAVED AQUATIC PLANTS			
American pondweed (*Potamogeton nodosus* Poir.)	Use one of the following:		
	endothall (10% G)	1 ppm	Spread on water
	endothall (potassium salt, 4.23 lb/gal)	1/2 cup/gal	Apply to leaves
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface
Waterlily (*Nymphaea* spp.)	Use one of the following:		
	dichlobenil (aquatic granules 10%)	50 lb/A	Spread on water
	2,4-D (20% G)	200 lb/A	Spread on water
	fluridone Sonar (4AS,5P, SRP)	Rate is dependent on water depth (see label)	Apply to water surface

*Sold under the trade name of Komeen by Sandoz Corporation.

Group and species	Herbicide	Rate of application	Remarks
FREE-FLOATING AQUATIC PLANTS			
Common duckweed (*Lemna minor L.*)	Use one of the following:		
	endothall (potassium salt, 4.23 lb/gal)	1 cup/4 gal	Apply to leaves
	diquat cation (2 lb/gal)	1 cup/4 gal	Apply to leaves
	simazine (80WP)	1 to 2 ppm	Apply to total water volume
	fluridone Sonar (4AS, 5P, SRP)	Rate is dependent on water depth (see label)	Apply to leaves and water surface
Watermeal (*Wolffia columbiana Karst.*)	simazine (80WP)	1 ppm	Apply to total water volume
ALGAE			
Chara (has cylindrical, whorled branches and resembles, in form, submersed aquatic plants (*Chara* spp.)	Use one of the following:		
	dichlobenil (aquatic granules 10%)	40 lb/A	Preemergent application only
	copper sulfate*	1 ppm	Postemergent application
Filamentous algae	copper sulfate*	1 ppm (copper)	Postemergent
	simazine (80WP)	0.5 to 1 ppm	Apply to total water volume

*Crystalline copper sulfate can be used; there are several copper-containing formulations that contain copper-chelating compounds, which prevent the immediate precipitation of copper carbonate. Check the label for instructions concerning their uses and rate of application. A lower rate of application for copper can be used with these latter formulations. Their copper contents may vary.

ADDITIONAL INFORMATION

Aquatic Weeds: Their Identification and Methods of Control. Fishery Bulletin No. 4, Illinois Department of Conservation, Division of Fisheries, Springfield, IL 62706.

Controlling Johnsongrass, Shattercane, and Sorghum-almum in Illinois

D. Anderson and M. McGlamery

Johnsongrass (*Sorghum halepense*) is a perennial that reproduces by seeds and rhizomes. Johnsongrass is a problem weed in Illinois, particularly in the southern half of the state where the rhizomes can overwinter. In the colder climate of northern Illinois, johnsongrass spreads primarily by seed.

Johnsongrass rhizomes are freely branching, fleshy, scaly, and white with purple spots. They may grow to several feet in length and may reach a diameter of 0.75 inch. The plant may be from 3 to 10 feet tall, depending on the biotype and environment. Johnsongrass has a large, open, panicle-type seedhead that is purplish, hairy, and diversely branched. The seeds are oval with a glossy mahogany cast. They are 0.13- to 0.15-inch long and are enclosed in straw- colored glumes.

Shattercane (*Sorghum bicolor*), often called wild cane, is an annual that reproduces only by seed. Although shattercane does not produce rhizomes, it can be almost as difficult to control as the perennial sorghums because it is capable of producing several flushes of seedlings in one season.

Shattercane closely resembles cultivated sorghum or sudangrass. The plant readily tillers so several stems may grow from a single crown. Shattercane has a panicle-type seedhead that varies from compact to loose to open. The seeds are oval and are usually enclosed in shiny black to dark mahogany glumes. The seedheads may droop to one side at maturity. The seeds usually shatter before the crop is harvested.

Sorghum-almum (*Sorghum almum*) is a cross between johnsongrass and a cultivated sorghum. This cross produces a plant with uneven sets of chromosomes so sorghum-almums with a range of characteristics between johnsongrass and shattercane can be found. Some plants have no rhizomes; others have short rhizome spurs that grow upward towards the soil surface; and still others have true johnsongrass-like rhizomes. The plant reproduces primarily by seed. However, some of the rhizomes may survive a mild winter if they are deep enough in the soil. In this case, new plants may be produced from those rhizomes the following spring.

Sorghum-almum generally resembles shattercane in its vegetative characteristics. Various seedhead types exist because of the plant's genetic variability. Often the seeds are smaller than shattercane but less elongated than johnsongrass; however, the seeds too are variable in appearance.

PREVENTION

Prevention of the establishment of the weedy sorghum species is an essential part of the overall control program. Johnsongrass, sorghum-almum, and shattercane can be spread by birds, livestock, or water, or by contaminated feed, machinery, or crop seed. The seeds remain viable in the soil for a long period of time. Therefore, many areas are continually plagued with new seedlings even though established plants are controlled.

New johnsongrass and sorghum-almum plants also develop from overwintering rhizome buds located at each rhizome node. When rhizome pieces are moved and deposited into clean soil, the area may become infested.

Whether you are attempting to prevent initial infestation or minimize reinfestation after a successful control program, it is important that you scout your fields and nearby noncrop areas regularly and destroy any of these plants before they establish and spread.

Take the following precautions to prevent the spread of weedy sorghum seeds and rhizomes:

1. Plant only clean crop seed that is free of johnsongrass, shattercane, and sorghum-almum seed.

2. When planting sorghum, plant only pure, cultivated sorghum seed that has been produced under proper isolation to reduce cross-pollination. Cut forage-type sorghums of sorghum-sudan hybrids before the seed matures.

3. Do not bring straw and hay from an infested area into a noninfested area.

4. Do not move livestock from an infested pasture into a noninfested field.

5. Clean all machinery, particularly combines where seeds might lodge, before moving it from an infested to a noninfested field.

6. Avoid dragging rhizome pieces on farm implements from an infested area to a noninfested area.

7. Immediately rogue or spot treat all plants when they appear.

8. Do not let plants develop mature seed. As soon as seedheads emerge, cut them from the plant. Then carry the seedheads out of the field and burn them or bury them in a common "grave."

CONTROL PROGRAMS

Effective long-term control of shattercane, johnsongrass, and sorghum-almum involves integrating cultural, mechanical, preventative, and chemical methods that prevent seed and rhizome production and reduce the number of viable seeds in the soil. Several years of good management are required to totally rid an area of these species.

Corn and Soybean Programs

The weedy sorghum species are quite tolerant of most corn herbicides (Table 1). Thiocarbamates are the only corn herbicides that are the most active against the sorghums, and these herbicides must be incorporated. For these reasons, the sorghums are especially difficult to manage where no-till or continuous corn is grown. Certain herbicides can be used to add some postemergence activity. Some new selective postemergence herbicides for corn are currently being tested. These products should greatly improve our ability to manage the weedy sorghums in corn.

Rotation to soybeans allows the use of more effective herbicides (Table 2). The soil-applied soybean herbicides are more effective than the corn herbicides but usually do not provide total control. Several selective postemergence herbicides are available that are very effective against grass weeds. A disadvantage with using these products is timing. Since sorghum species emerge later than many of the common annual grasses, it is not possible to use one application to control all grass species for the entire season.

The basic control strategies for soybeans include: applying a dinitroaniline (DNA) herbicide followed by a postemergence herbicide (broadcast or band plus cultivation); applying a split application of a postemergence herbicide; and planting soybeans for two consecutive years to allow a 2X rate of a dinitroaniline herbicide the first year.

Soil-applied Herbicides in Corn and Soybeans. Proper soil preparation is critical for soil-applied herbicides to effectively control seedlings and rhizomes. Before incorporating a preplant herbicide, prepare the ground with a chisel plow to bring rhizomes to the surface and then disk to cut them into small pieces. If the primary tillage operation is conducted in the fall, the rhizome pieces will be exposed to freezing and thawing, which reduces their viability. After large soil clods and excess residues are minimized, the field is ready for a preplant-incorporated herbicide.

If the weedy sorghum has just been introduced into the area and you are attempting to control seedlings before the infestation is well established, it is better to minimize the amount of mixing of the seeds in the soil. This will prevent their being buried where they can be dormant for several years and later brought to the surface.

Uniform distribution of the herbicide applied at the rate labeled for johnson-grass, sorghum-almum, or shattercane is essential if a soil-applied treatment is going to be effective. Improper herbicide incorporation or low herbicide use rates often result in poor control. Disk twice with the second disking at an angle to the first. A tandem disk puts the herbicide at about half the operational depth; therefore, set and operate the disk to cut 4 to 6 inches for the first disking and, at most, 4 inches for the second disking. Do not incorporate the herbicide deeper than 3 inches. Most of the soil-applied herbicides used for the control of weedy sorghum species will benefit from immediate incorporation to minimize the amount of herbicide lost.

Most preplant-incorporated herbicides must be applied at a considerably higher rate to control the sorghum species than most annual grasses. Even at the higher rate, these treatments only suppress plants emerging from rhizomes and they often allow some seedlings to escape. Seedling control can be good if conditions are ideal.

Cultivation is usually required regardless of the preplant herbicide used. This is especially important in corn because we currently have no effective postemergence herbicides. Time the cultivations carefully. To control johnsongrass and sorghum-almum, repeat the cultivations at intervals of two to three weeks in order to prevent new rhizome growth. Shattercane plants need to be destroyed before they develop seedheads. Set the cultivator sweeps for shallow cultivation--2 inches or less--and avoid cultivating below the depth at which the herbicide was incorporated. Deep cultivation brings untreated soil containing viable seeds to the surface where the seeds can germinate.

Postemergence Grass Herbicides in Soybeans. These herbicides provide excellent seedling control and rhizome suppression of control. Retreatment with a reduced rate is often necessary for rhizome control, especially in no-till fields where the recommended soil-applied herbicide was not used. Assure and Fusilade have generally provided better rhizome control from a single application than the other products. Select the appropriate rate according to weed size. Follow the label recommendations on the use of a surfactant or crop oil concentrate.

Foliar Spot-Treatment. Scattered plants of johnsongrass, sorghum-almum, and shattercane that are not controlled by soil-applied herbicides or cultivation should be controlled by other methods. Roguing or spot-treating with glyphosate (Roundup) is an integral part of the control program. Plants that escape will produce seeds (shattercane) or both seeds and rhizomes (the perennial sorghums) that will reinfest the field.

Roundup is the only herbicide presently labeled for spot application in corn and soybeans. Applying Roundup as a spot treatment or with selective application equipment is more effective in soybeans than in corn because the size of the soybean plants allows for easier spot application of the herbicide. A spot application is made with a 1 percent solution (1-1/2 ounces of Roundup per gallon of water). A directed application is a 33 percent solution (1 gallon of Roundup per 2 gallons of water) applied with a recirculating sprayer or ropewick applicator. Shattercane should be treated before it produces seedheads, and the perennial sorghums should be treated in the boot stage or when plants are at least 18 inches tall. Make the application carefully because crop plants sprayed with Roundup will be severely injured. It can also kill or severely injure crops and other desirable plants if it is applied to or drifts onto them.

Winter Grain and Fallow Programs

Winter grain production followed by summer fallow can effectively reduce stands of weedy sorghums as well as prevent the production of seeds and rhizomes and reduce their number in the soil. For this program to be successful, all sorghum plants that emerge during the period of fallow must be destroyed before they produce seeds or rhizomes.

After the small grain is harvested, plow and disk as thoroughly as your soil type and slope will allow. Repeat the diskings at intervals of two to three weeks to destroy seedlings and to keep emerging plants from developing rhizomes. Tillage can destroy weed seedlings by covering them with soil or by allowing them to desiccate. Cutting rhizomes into small sections can reduce their viability by exposing them to drying conditions.

Where tillage is not an acceptable option following a grain crop, apply Roundup as a broadcast or spot application for rhizome and seedling control (Table 3). Often an additional application is required later in the season to control new seedlings or regrowth from rhizomes. For the control program to be most effective, it is important that all plants be destroyed when they appear. Otherwise your earlier efforts will have been futile because the field will become reinfested.

Use a good seedling control program when returning to row crops after the production of winter grain or forage, or reinfestations may occur.

Forage, Grazing, and Mowing Programs

A competitive forage crop, such as alfalfa, can somewhat reduce the competitiveness of shattercane, johnsongrass, and sorghum-almum seedlings. Regular harvesting, grazing, or repeated mowings of forage crops reduces seed production and rhizome vigor. Although pasturing and mowing will not eliminate the weed, the weakened plants will be more susceptible to other control measures.

Noncropland Programs

Johnsongrass, sorghum-almum, and shattercane plants in fencerows and other noncrop areas are potential sources for reinfestations of crop areas. Eliminate all weedy sorghum plants in noncrop areas to prevent further seed or rhizome production that will allow the weed to spread. Roundup can be used to treat large infestations of the weeds. Several other herbicides are labeled as well (Table 4). Dense johnsongrass infestations will probably require retreatment.

Even after successfully managing your weedy sorghum for several years, new infestations can develop from dormant seed in the soil or from newly introduced seed. Scout your fields and noncrop areas regularly, and immediately rogue or spot-treat any weeds that develop.

Some of the herbicides labeled for use in noncropland areas have long soil life and may be mobile in the soil. Do not use these herbicides where you plan to grow crops in the near future or where conditions are conducive for their movement into groundwater. Most labels specify that the treated area should not be grazed or the treated plants fed to livestock.

Table 1. Control of Johnsongrass, Shattercane, and Sorghum-almum with Corn Herbicides

Herbicide	Rate per acre	Remarks
Preplant-incorporated (PPI) application: seedling control and rhizome suppression		
Eradicane Extra 6E	8 pt	
Eradicane 6.7E	7 1/3 pt	
Sutan + 6.7E	7 1/3 pt	
Genate Plus 6.7E	7 1/3 pt	
Postemergence (POE) soil application with incorporation		
Prowl 4E	1.5 to 3.0 pt	Corn 4 inches to layby. Cultivate before application to cover base of corn plant. Lightly incorporate.
Treflan 4E	1 to 2 pt	Corn at least 8 inches. Cultivate before application to cover base of corn plant. Lightly incorporate.
Postemergence (POE) spot treatment		
Roundup 4E	1% solution (1 1/2 oz per gal of water)	

Table 2. Control of Johnsongrass, Shattercane, and Sorghum-almum with Soybean Herbicides

Herbicide	Rate per acre	Remarks	
Preplant-incorporated (PPI) application: seedling control			
Prowl 4E	2 to 3 pt		
Sonalan 3E	2 to 3 pt		
Treflan 4E	2 to 2 1/2 pt		
Pursuit Plus	2 1/2 pt		
Preplant-incorporated application: seedling control and rhizome suppression			
Treflan 4E	2 to 4 pt		
Prowl 4E	2 to 4 pt		
Postemergence (POE) application: seedling control			
		Shattercane height	Johnsongrass or sorghum-almum height
Assure 0.8E	10 fl oz	6 to 12 inches	2 to 8 inches
Fusilade 2000 1E	12 fl oz	6 to 12 inches	2 to 8 inches
Option 1E	13 fl oz	6 to 12 inches	4 to 10 inches
Poast 1.5E	16 fl oz	6 to 18 inches	less than 8 inches
Poast Plus 1E	24 fl oz	6 to 18 inches	less than 8 inches
Pursuit 2S	4 fl oz	1 to 8 inches	1 to 8 inches
Postemergence (POE) application: seedling and rhizome control			
		Johnsongrass or sorghum-almum height	
Assure 0.8E			
1st application	20 fl oz	10 to 24 inches	
2nd application	14 fl oz	6 to 10 inches	
Fusilade 2000 1E			
1st application	24 fl oz	8 to 18 inches	
2nd application	16 fl oz	4 to 12 inches	
Option 1E:			
1st application	19 fl oz	10 to 20 inches	
2nd application	13 fl oz	10 to 20 inches	
Poast 1.5E			
1st application	16 fl oz	15 to 20 inches	
2nd application	16 fl oz	6 to 12 inches	
Poast Plus 1E			
1st application	24 fl oz	15 to 25 inches	
2nd application	24 fl oz	6 to 12 inches	
Postemergence spot treatment			
Roundup 4E	1% solution (1 1/2 oz per gal of water)		
Postemergence directed treatment (ropewick applicator or recirculating sprayer)			
Roundup 4E	33% solution (1 gal per 2 gal of water or 5 oz per 1 gal of water)		

Table 3. Control of Johnsongrass, Shattercane, and Sorghum-almum on Fallow Ground or Noncropland

Herbicide	Rate per acre	Remarks
Postemergence (POE) broadcast applications		
Roundup 4E	12 oz	Shattercane up to 12 inches tall.
Roundup 4E	1 to 3 qt	Plants 18 inches tall.
Postemergence (POE) spot applications		
Roundup 4E	1% solution (1 1/2 oz per gal of water)	

*Table 4. Control of Johnsongrass, Shattercane, and Sorghum-almum on Noncropland Only**

Herbicide	Rate	Remarks
Soil-applied spot application		
Arsenal 5G	20 lb/A	Distribute evenly.
Pramitol 5PS	2 lb/100 sq ft	Contains sodium chlorate for additional activity.
Hyvar X-L (3 lb/gal)	6 to 12 gal/A	Soil or stubble.
Sodium chlorate	2 to 4 lb/100 sq ft	Can be applied to emerged plants. Mix with borax to reduce fire hazard.
Postemergence (POE) spot application		
Asulox	1 to 2 gal/A	Plants 18 inches tall; no soil activity.
DSMA	2 qt/A	Repeat weekly as needed; no soil activity.
MSMA (Daconate)	2 qt/A	Repeat weekly as needed; no soil activity.
Pramitol 25E	4 to 5.5 pt/1,000 sq ft	Foliar or stubble. Distribute thoroughly.
Oust	2 to 5 oz/A	Early postemergence. Temporary suppression; retreat regrowth.
Oust	6 to 12 oz/A	Early postemergence.

*Herbicides with long residual activity should not be used where you have plans for crops in the near future or where conditions are conducive for the herbicide to move into surface waters or the groundwater.

The Toxicity of Herbicides

D. Anderson and M. McGlamery

Toxicity is the capacity of a substance to produce injury. Toxic effect can be immediate (acute) or accumulative (chronic), depending upon the exposure duration, the dose, and the herbicide. Toxicity varies with the animal species, age, sex, and nutritional status and with the route of exposure--oral (stomach), inhalation (lungs), or dermal (skin). Eye and skin effects are also of concern.

Pesticide manufacturers are required to conduct acute, subacute, and chronic toxicity tests as well as mutagenic, teratogenic, and carcinogenic tests. The usual expression of toxicity is called the LD_{50}, which is the average lethal dose in milligrams per unit of body weight in kilograms required to kill 50 percent of a test population. Toxicity tests are usually conducted on white rats, mice, or rabbits.

Conversion factors to convert milligrams per kilogram (mg/kg) of body weight are:

$$\text{mg/kg} \times 0.0016 = \text{ounces/100 pounds}$$
$$\text{mg/kg} \times 0.0030 = \text{ounces/187 pounds}$$

Because toxicity depends upon body weight, the amount of chemical considered lethal for a child is less than the amount for an adult. And conversely, it takes more to kill a large animal than a small one.

The classes of toxicity are given in the table below. The herbicide label will indicate the extent of toxicity by the signal word it carries.

Toxicity class	**Label signal words**	**Oral LD_{50} (mg/kg)**	**Dermal LD_{50} (mg/kg)**	**Inhalation LC_{50}* (mg/liter)**
High	Danger-Poison	<50	<200	<0.2
Moderate	Warning	50 to 500	200 to 2,000	0.2 to 2
Low	Caution	500 to 5,000	2,000 to 20,000	2 to 20
Very Low	Caution	5,000+	20,000+	20+

*LC_{50} = Concentration of pesticide, in milligrams per liter of air space, required to kill 50 percent of a test population.

Danger-Poison. Herbicides that carry these signal words plus a skull and crossbones contain the active ingredient endothall or paraquat. Endothall is available in liquid form as Aquathol K (3S) and as Hydrothol 191 (2S). Paraquat is available as ICI's Gramoxone Super and Gramoxone Extra.

These herbicide labels carry precautions: The user is advised to wear goggles or a face shield as well as rubber gloves and a rubber apron when working with concentrates. Avoid breathing spray mists.

Danger-Corrosive. These signal words indicate the risk of irreversible eye or skin burns. This warning is usually accompanied by a recommendation for the use of goggles or a face shield, especially when the user is handling concentrates. The label may also call for rubber gloves and an apron when the user is handling or mixing concentrates or adjusting equipment. The first aid statement says: "In case of contact with eyes, immediately flush eyes with plenty of water for at least 15 minutes and **get medical attention promptly.**" If the contact is on the skin, the label calls for washing the skin with plenty of water. If skin irritation occurs, medical attention should be sought. Herbicides in this category are:

Trade name	Common name	Trade name	Common name
Aquathol 7G	endothall	Krovar I 80DG	bromacil + diuron
Balan 1.5EC	benefin	Laddok 3.33L	bentazon + atrazine
Blazer 2L	acifluorfen	Lasso 4EC	alachlor
Bronco 4WDL	alachlor + glyphosate	Pramitol 25E, 5PS	prometon
Butyrac 200	2,4-DB	Squadron 2.33L	imazaquin + pendimethalin
Cobra 2E	lactofen	Storm 4E	acifluorfen + bentazon
Commence 5.25E	clomazone + trifluralin	Sutazine 6ME	butylate + atrazine
Devrinol 2E	napropamide	Tackle 2S	acifluorfen
Galaxy 3.67E	acifluorfen + bentazon	Velpar 2L	hexazinone
Garlon 3A	triclopyr amine	Weedar 64, 64A	2,4-D amine
Hoelon 3EC	diclofop-methyl	Weedone 638	2,4-D amine + ester
Hydrothal 191	endothall		

Warning. Warning is the signal word used for herbicides containing the active ingredient cyanazine or bromoxynil, which are moderately toxic through oral, dermal, or inhalation exposure. These herbicide labels state the following under Human Precautions: "May be fatal or harmful if swallowed, inhaled, or absorbed through the skin."

Cyanazine	Bromoxynil	Diquat
Bladex 4L, 90DF	Buctril	Diquat
Extrazine II 4L, 90DF		

"Warning" also appears as a signal word on other herbicides with label statements indicating that they can cause eye or skin irritation or burns, or may be harmful if swallowed, inhaled, or absorbed through the skin. Herbicides in this category are listed below and on the following page.

Most of these herbicide labels state: "Do not get into eyes or on skin." If skin or eye contact occurs, they call for washing the contacted areas thoroughly for 15 minutes and for calling a physician if eye contact occurs. Some herbicide labels recommend the use of goggles or face shield and other protective clothing. Fusilade, Goal, and Laddok labels specify the use of goggles or face shield. Dual, Fusilade, and Laddok labels also call for the use of rubber gloves.

Trade name	Common name	Trade name	Common name
Acclaim	fenoxaprop	Option	fenoxaprop
Alanap 2L	naptalam	Poast 1.5E	sethoxydim
Banvel 4S	dicamba	Poast Plus 1E	sethoxydim
Cannon 3E	alachlor + trifluralin	Prowl 4EC	pendimethalin
		Ramrod 4WDL, 20G	propachlor
Command 4EC	clomazone	Ramrod/atrazine 4WDL	propachlor + atrazine
Dalapon 85	dalapon		
DMA-4S	2,4-D amine	Reflex 2LC	fomesafen
Dowpon-M	dalapon	Rescue 2.06S	naptalam + 2,4-DB
Escort 60DF	metsulfuron		
Freedom	alachlor + trifluralin	Rodeo 5.4S	glyphosate
		Ronstar 2.5G	oxadiazon
Goal 2EC	oxyfluorfen	Roundup 4S	glyphosate
Harmony Extra	DPX-M6316 + DPX-L5300	Sodium TCA	TCA
		Sonalan 3EC	ethalfluralin
Hyvar X-L, 2WSL	bromacil	Squadron 2.33L	pendimethalin + imazaquin
Krenite 4S	fosamine		
Lariat	alachlor + atrazine	Tandem 4EC	tridiphane
		Treflan 4EC	trifluralin
Lasso II 15G	alachlor	Tri-Scept 3E	trifluralin + imazaquin
Lorox Plus 60DF	linuron + chlorimuron		
		Velpar 90WSP	hexazinone

The Environmental Hazards section of the label includes statements regarding toxicity to fish and wildlife. Herbicides that state that they are toxic to fish or wildlife contain the active ingredients bromoxynil, propachlor, or oxyfluorfen.

Bromoxynil	Propachlor	Other
Bronate	Ramrod 4F	Diquat (diquat)
Buctril	Ramrod 20G	Evik (ametryn)
Buctril/atrazine	Ramrod/atrazine	Goal (oxyfluorfen)
		Gramoxone (paraquat)
		Pramitol (prometon)

Some herbicide labels carry the statement "Toxic to Fish." These include certain esters of phenoxy and pyridinoxy-phenoxy herbicides, the dinitroaniline herbicides, and miscellaneous others. All herbicide labels warn the user to keep the product out of lakes and streams. With the above herbicides, however, the user has to be especially careful.

Phenoxy esters*	Oxy-phenoxy esters	Dinitroanilines	DNA mixes
Butoxone ester	Hoelon (diclofop)	Balan (benefin)	Commence (trifluralin + clomazone)
Butyrac ester	Fusilade (fluazifop)	Prowl (pendimethalin)	Prozine (pendimethalin + atrazine)
Esteron 44, 99	Verdict (halazifop)	Sonalan (ethalfluralin)	Salute (trifluralin + metribuzin)
Weedone 170	Whip (fenoxaprop)	Treflan (trifluralin)	Squadron (pendimethalin + imazaquin)
Weedone LV			Tri-Scept (trifluralin + imazaquin)

*There are many phenoxy herbicide products.

The potential for the contamination of groundwater with pesticides has prompted the addition of groundwater statements on several pesticide labels, especially those products containing atrazine, simazine, alachlor, metolachlor, or metribuzin. The following herbicides carry label statements cautioning the user to handle the herbicides in a manner that will minimize the potential for groundwater contamination.

Trade name	Common name	Trade name	Common name
AAtrex, Atrazine	atrazine	Griffex	atrazine
Arena	alachlor	Judge	alachlor
Bicep	atrazine + metolachlor	Laddok	atrazine + bentazon
Bladex	cyanazine	Lariat	atrazine + alachlor
Bronco	alachlor + glyphosate	Lasso	alachlor
Buctril/atrazine	bromoxynil + atrazine	Lexone	metribuzin
Bullet	atrazine + alachlor	Preview	metribuzin + chlorimuron
Cannon	alachlor + trifluralin	Princep	simazine
Canopy	metribuzin + chlorimuron	Ramrod/atrazine	propachlor + atrazine
Confidence	alachlor	Saddle	alachlor
Dual	metolachlor	Salute	trifluralin + metribuzin
Extrazine II	cyanazine + atrazine	Sencor	metribuzin
Freedom	alachlor + trifluralin	Sim-Trol	simazine
		Stall	alachlor
		Turbo	metribuzin + metolachlor

Herbicide labels carry precautions about human and environmental hazards and are also labeled with signal words--Danger-Poison, Danger-Corrosive, and Warning. *Always read and heed the label!*

Herbicides, Formulations, and Toxicities

D. Anderson and M. McGlamery

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
AAtrex[§]	atrazine					
80W	*Ciba-Geigy*	5,100	9,300	moderate	mild	Caution
4L		1,075	> 5,000	mild	mild	Caution
Nine-O (90 WDG)		1,600	>10,000	mild	mild	Caution
Access*	triclopyr + picloram					
3E	(2 + 1 lb) *Dow*	2,525	> 2,000	moderate	moderate	Caution
Acclaim	fenoxaprop					
1EC	*Hoechst*	> 3,310	> 2,000	mild	moderate	Warning
Alanap-L	naptalam					
2EC	*Uniroyal*	1,770		mild	moderate	Warning
Ala-Scept	alachlor + imazaquin (32:1)					
3.19E	(3 + .19 lb) *American Cyanamid*	3,062	> 2,000	moderate	severe-irreversible	DANGER-corrosive
Ally	metsulfuron					
60 DF	methyl *DuPont*	> 5,000	> 2,000	mild	mild	Caution
Amiben	chloramben					
2S	*Rhone-Poulenc*	7,546	> 2,000	mild	mild	Caution
10G		> 5,000	> 2,000	mild	slight	Caution
75DS		3,300	> 2,000	none	mild	Caution
Amitrol-T*	amitrole					
2S	*Rhone-Poulenc*	10,480	>10,000	moderate	moderate	Caution-(carcinogenic)
Amizol*	amitrole					
90WSP	*Rhone-Poulenc*	14,700	>10,000	none	slight	Caution-(carcinogenic)

NOTE: A blank indicates that the information is not available at this time.
*Restricted-use pesticide (RUP)
[§]Groundwater advisory
[a]EC or E means emulsifiable concentrate; G, granules; L, liquid; S, water-soluble liquid; WDG, water-dispersible granule; WDL, water-dispersible liquid; WP or W, wettable powder; WSP, water-soluble powder; DF, dry flowable; P, pellet; F, flowable; ME, micro-encapsulated. Liquid formulations (EC, E, L, S, WDL, F) are in pounds per gallon; dry formulations (G, WDG, WP, WSP, DF, P) are in percentages.
[b]Weed Science Society of America approved name or experimental number.
[c]LD_{50} means the milligrams of chemical per kilogram of body weight that are lethal to 50 percent of a population of test animals, usually white rats, when administered in a single, oral dose.
[d]LD_{50} means the milligrams of chemical per kilogram of body weight that are lethal to 50 percent of a population of test animals, usually rabbits, when administered in a single, dermal dose.
[e]Dermal irritation is determined by applying an amount of pesticide onto the skin of shaved test animals.
[f]Eye irritation is determined by applying an amount of pesticide into the eye of test animals.

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Aquathol	endothall					
K (3S)	*Pennwalt*	125	171	severe	severe-corrosive	DANGER-Poison
7G		1,340	>10,000	moderate	severe-corrosive	DANGER
Aquazine	simazine					
80W	*Ciba-Geigy*	>15,380	>10,200	mild	mild	Caution
Arsenal	imazapyr					
2L	*American Cyanamid*	> 5,000	> 2,148	mild	mild	Caution
Arsonate	MSMA					
6.6S	*Fermenta*	1,700	2,500	mild	mild	Caution
Assure	quizalofop					
0.8EC	*DuPont*	> 5,000	> 2,000	mild	mild	Caution
Asulox	asulam					
3.34S	*Rhone-Poulenc*	> 8,000	> 1,000	mild	mild	Caution
Atrazine	atrazine					
80W	*DuPont*	5,100	9,300	moderate	mild	Caution
4L		1,075	> 5,000	mild	mild	Caution
Balan	benefin					
1.5EC	*Elanco*	> 500	> 2,000	moderate	severe	DANGER
2.5G		> 2,500	> 5,000	slight	moderate	Caution
60DF		> 500	> 2,000	moderate	moderate	Caution
Banvel	dicamba					
4S	*Sandoz*	2,629	> 2,000	moderate	severe	Warning-Corrosive
Banvel 720	dicamba + 2,4-D (1:2)					
3S	(1 + 2 lb) *Sandoz*	2,500			moderate	Caution
Basagran	bentazon					
4S	*BASF*	1,860	> 2,450	moderate	moderate	Caution
Betasan	bensulide					
3.6G	*ICI Americas*	> 1,000	> 5,000	none	moderate	Caution
7G		3,549	> 2,000	none	moderate	Warning
12.5G		1,987	> 2,000	none	moderate	Warning
4E		1,115	> 2,000	mild	severe	Caution
2.9E		1,420	> 2,000	mild	moderate	Caution
Bicep[§]	metolachlor + atrazine					
6L	(3.33 + 2.67 lb)	4,060	> 2,010	moderate	moderate	Caution
4.5L	(2.5 + 2 lb) *Ciba-Geigy*	4,680	> 2,000	slight	mild	Caution
Bladex*[§]	cyanazine					
90DF	*DuPont*	266	> 2,000	mild	moderate	Warning
4L		473	> 2,000	slight	mild	Warning
Blazer	acifluorfen					
2S	*BASF*	4,790	3,250	moderate	severe	DANGER

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Bronco*§ 4 WDL	alachlor + glyphosate (2.6 + 1.4 lb) *Monsanto*	3,152	> 5,000	slight	severe	DANGER
Buctril* 2EC	bromoxynil *Rhone-Poulenc*	780	> 2,000	moderate	moderate	Warning
Buctril + Atrazine*§ 3WDL	bromoxynil + atrazine (1:2) (1 + 2 lb) *Rhone-Poulenc*	3,600	> 2,000	none	moderate	Caution
Bullet*§ 4MT	alachlor + atrazine (2.5 + 1.5 lb) *Monsanto*	8,900	> 5,000	slight	slight	Caution
Butoxone 1.75EC	2,4-DB *Cedar*	1,960	>10,000	mild		
Butyrac 200 2EC	2,4-DB *Rhone-Poulenc*	1,706	1,440	moderate	severe	DANGER-Corrosive
Butyrac Ester 2EC	2,4-DB *Rhone-Poulenc*	2,270	1,230	moderate	slight	Warning
Cannon*§ 3EC	alachlor + trifluralin (2.5 + 0.5 lb) *Monsanto*	3,150	> 5,000	slight	moderate	Warning
Canopy§	metribuzin + chlorimuron (64.3% + 10.7%) *DuPont*	1,500	> 2,000	slight	mild	Caution
Casoron 50W 4G	dichlobenil *Uniroyal*	3,160	1,350	mild	mild	 Caution Caution
Chipco Turf 2EC	mecoprop (MCPP) *Rhone-Poulenc*	930	900	moderate	moderate	Caution
Classic 25DF	chlorimuron *DuPont*	> 5,000	> 2,000	mild	mild	Caution
Cobra 2E	lactofen *Valent*	2,530	> 2,000	severe	severe	DANGER
Command 4EC	clomazone *FMC*	2,235	> 2,000	mild	moderate	Warning
Commence 5.25EC	trifluralin + clomazone (3 + 2.25 lb) *Elanco and FMC*	> 500	> 5,000	moderate	severe	DANGER
Contain 1S	imazapyr *American Cyanamid*	> 5,000	> 2,000	none	slight	Caution

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Crossbow	triclopyr + 2,4-D (1:2)					
3EC	(1 + 2 lb) *Dow*	1,792	1,796	mild	slight	Caution
Curtail	clopyralid + 2,4-D					
2.4S	(.38 + 2 lb) *Dow*	> 2,830	> 4,000	moderate	severe	DANGER-Flammable
Cutless	flurprimidol					
50W	*Elanco*	1,250	> 5,000	slight	moderate	Caution
T.P.		> 700	> 5,000	slight	moderate	Caution
Dacthal	DCPA					
75WP	*Fermenta*	>10,000	>10,000	none	moderate	Warning
Dalapon-85	dalapon					
74WSP	*Fermenta*	7,570		moderate		Caution
Devrinol	napropamide					
50WP	*ICI Americas*	2,710	> 4,640	mild	mild	Caution
10G		> 5,000	> 5,000	none	none	Caution
5G		> 5,000	> 5,000	none	moderate	Caution
2G		> 5,000	> 5,000	none	moderate	Caution
2E		3,690	> 5,000	moderate	severe	DANGER-Corrosive
Diquat	diquat					
2S	*Valent*	230	> 400	moderate	moderate	Warning
Dowpon-M	dalapon					
74WSP	*Cedar*	7,570		moderate		Caution
Dozer	fenuron TCA	4,000		moderate		
3L	*Hopkins*					
25P						
Dual[§]	metolachlor					
8E	*Ciba-Geigy*	> 820	> 5,009	slight	mild	Caution
25G		> 5,000	> 2,000	mild	slight	Caution
Endothal	endothall					
Turf 1.2S	*Pennwalt*	198	> 2,000	severe-corrosive	severe-corrosive	
Enide	diphenamid					
90WP	*Nor-Am*	970	> 6,320	mild	mild	Caution
Eptam	EPTC					
7E	*ICI Americas*	1,325	2,750	mild	moderate	Caution
10G		> 5,000	> 5,000	none	moderate	Caution
Eradicane	EPTC + safener					
6.7E	*ICI Americas*	> 2,000	3,830	mild	severe	Caution
Eradicane Extra	EPTC + safener + extender					
6E	*ICI Americas*	776	> 2,000	mild	moderate	Caution
Escort	metsulfuron					
60DF	*DuPont*	> 5,000	> 2,000	none	moderate	Warning

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Evik 80WP	ametryn *Ciba-Geigy*	1,950	> 3,100	mild	mild	Caution
Extrazine II*[§]	cyanazine + atrazine (3:1)					
90DF	(67.5% + 22.5%)	369	> 2,000	mild	mild	Warning
4L	(3 + 1 lb) *DuPont*	366	> 2,200	slight	mild	Warning
Freedom*[§]	alachlor + trifluralin					
3EC	(2.67 + 0.33 lb) *Monsanto*	2,650	> 5,000	severe	severe	Warning
Fusilade 2000 1EC	fluazifop-butyl *ICI Americas*	4,350	> 2,000	mild	mild	Caution
Galaxy	acifluorfen + bentazon (1:4.5)					
3.67S	(.67 + 3.0 lb) *BASF*			moderate	severe	DANGER
Gallery 75 DF	isoxaben *Elanco*	> 5,000	> 5,000	moderate	moderate	Caution
Garlon	triclopyr					
3A	*Dow*	2,830	> 3,980	moderate	severe	DANGER
4E		2,460	2,315	moderate	mild	Caution
Genate Plus 6.7EC	butylate *Valent*	3,878	4,640	moderate		Caution
Genep 7EC	EPTC *Valent*	1,652	10,000	mild	mild	Caution
Goal 2EC	oxyfluorfen *Rohm & Haas*	5,800	> 3,000	moderate	moderate	Warning
Gramoxone Extra* 2.5S	paraquat *ICI Americas*	30	240	severe	severe	DANGER-Poison
Gramoxone Super* 1.5S	paraquat *ICI Americas*	120	> 480	moderate	moderate	DANGER-Poison
Harmony Extra 75DF	DPX-M6313 + DPX-L5300 (50% + 25%) *DuPont*	> 5,000	> 2,000	mild	moderate	Warning
Hoelon* 3EC	diclofop-methyl *Hoechst*	2,176	640	moderate	moderate	DANGER-(possible carcinogen)
Hydrothal 191	endothall					
2S	*Pennwalt*	221	50	severe	severe-corrosive	DANGER-Poison
5G		1,540	>10,000	moderate	severe-corrosive	DANGER
Hyvar	bromacil					
X (80WP)	*DuPont*	5,000	> 5,000	moderate	slight	Caution
X-L (2WSL)						Warning

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Karmex	diuron					
80DF	*DuPont*	6,964	> 2,000	none	moderate	Warning
Kerb	pronamide					
50WP	*Rohm & Haas*	5,620	> 3,160	mild		Caution
Kleenup	glyphosate	5,600	> 5,000			
0.55	*Ortho*			slight	slight	
Krenite	fosamine					
4L	*DuPont*	7,380	> 1,680	mild	none	Caution
S (4L)		> 5,000	> 5,000	mild	moderate	Warning
Krovar I	bromacil + diuron					
80DF	(40% + 40%)	> 2,500	> 2,000	severe	mild	DANGER
80WP	(40% + 40%) *DuPont*	5,980	> 7,500	moderate	mild	Caution
Krovar II	bromacil + diuron					
80DF	(53% + 27%) *DuPont*	3,816	> 2,000	moderate	moderate	Caution
Laddok§	bentazon + atrazine (1:1)					
3.33L	(1.67 + 1.67 lb) *BASF*	3,340		moderate	moderate	DANGER-Corrosive
Lariat*§	alachlor + atrazine (5:3)					
4F	(2.5 + 1.5 lb) *Monsanto*	4,400	> 5,000	severe	moderate	Warning
Lasso*§	alachlor					
4MT	*Monsanto*	> 5,000	> 5,000	mild	mild	Caution
II (15G)		5,800	16,000	slight	severe	Warning
4EC		2,000	7,800	moderate	severe	DANGER
Lexone§	metribuzin					
4L	*DuPont*	2,890	> 7,500	none	moderate	Caution
75DF		2,795	>20,000	none	moderate	Caution
Linex	linuron	1,500			mild	Caution
4WDL	*Griffin*					
Lorox	linuron					
4L	*DuPont*	2,437				Caution
50DF		4,833	> 2,000	none	mild	Caution
Lorox Plus	chlorimuron + linuron (1:16)					
60DF	(3% + 57%) *DuPont*	1,800	> 2,000	moderate	severe	Warning
Marksman	dicamba + atrazine					
3.2F	(1.1 + 2.1 lb) *Sandoz*	5,900	> 2,000	mild	mild	Caution
Option	fenoxaprop					
1EC	*FMC*	> 3,310	> 2,000	mild	moderate	Warning

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Oust 75DG	sulfometuron methyl *DuPont*	> 5,000	> 2,000	none	mild	Caution
Passport 2.6 EC	trifluralin + imazethapyr (2.4 + .2 lb) *American Cyanamid*	3,674	> 2,000	mild	severe-irreversible	DANGER
Pennant 5G	metolachlor *Ciba-Geigy*	> 5,030	> 2,010	mild	slight	Caution
Pinnacle 25DF	DPX-M6316 *DuPont*	> 5,000	> 2,000	none	moderate	Caution
Poast 1.5E	sethoxydim *BASF*	4,900	> 4,000	moderate	moderate	Warning
Poast Plus 1E	sethoxydim *BASF*	> 2,200	> 2,000	moderate	moderate	Caution
Pramitol	prometon *Ciba-Geigy*					
25E (2EC)		2,110	2,000	severe	corrosive	DANGER-corrosive
5PS (5%)		2,745	> 2,000	severe	corrosive	DANGER-corrosive
Prefar 4E	bensulide *ICI Americas*	826	> 4,640	mild	moderate	Caution
Preview[§] 75DF	chlorimuron + metribuzin (7.5% + 67.5%) *DuPont*	1,500	2,000	none	moderate	Caution
Princep[§]	simazine *Ciba-Geigy*					
4L		> 5,000	> 2,500	slight	slight	Caution
80W		>15,380	>10,200	mild	mild	Caution
4G		> 5,070	> 2,010	slight	mild	Caution
90WDG		> 5,000	> 2,000	slight	slight	Caution
Probe 75WDG	methazole *Sandoz*	2,975	> 2,000	none	severe	Warning
Prowl 4EC	pendimethalin *American Cyanamid*	3,380	> 5,000	mild	moderate	Warning
Prozine 70DF	pendimethalin + atrazine (1:1) *American Cyanamid*	7,071	> 2,000	mild	mild	Caution
Pursuit 2EC	imazethapyr *American Cyanamid*	> 5,000	> 2,000	mild	none	Caution
Pursuit Plus	imazethapyr + pendimethalin (14:1) (0.2 + 2.8 lb) *American Cyanamid*	> 5,000	> 2,000			Caution
Ramrod	propachlor *Monsanto*					
4F		3,269	4,194	severe-corrosive	moderate	Warning
20G		4,000	>20,000	slight	severe-corrosive	Warning

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Dermal[d]	Irritation Dermal[e]	Eye[f]	Label signal word
Ramrod/ Atrazine[§] 4L	propachlor + atrazine (3:1) (3 + 1 lb) *Monsanto*	2,374	> 5,000	slight	moderate	Warning
Reflex 2LC	fomesafen *ICI Americas*	> 5,000	> 2,000	mild	moderate	Warning-Carcinogenic
Rescue 2.06EC	naptalam + 2,4-DB (2 + .06 lb) *Uniroyal*			mild	moderate	Warning
Rodeo 5.4S (4 a.e.)	glyphosate *Monsanto*	> 5,000	> 5,000	mild	none	Warning
Ronstar	oxadiazon *Rhone-Poulenc*					
2.5G		> 5,000	> 2,000	moderate	mild	Warning
50WP		> 5,000	> 2,000	severe	moderate	Warning
Roundup 4S (3 a.e.)	glyphosate *Monsanto*	5,400	> 5,000	moderate	slight	Warning
Salute[§] 4E	metribuzin + trifluralin (1.33 + 2.67 lb) *Mobay*	1,561	> 2,000	mild	mild	Caution
Scepter	imazaquin *American Cyanamid*					
1.5EC		> 5,000	> 5,000	mild	mild	Caution
70DG		6,156	> 2,000	none	mild	Caution
Sencor[§]	metribuzin *Mobay*					
4L		> 1,500	>20,000	none	none	Caution
75DF		2,379	> 5,000	slight	moderate	Caution
Sinbar 80WP	terbacil *DuPont*	> 5,000	> 5,000	none	mild	Caution
Snapshot	isoxaben + oryzalin *Elanco*					Caution
Solicam 80DF	norflurazon *Sandoz*	> 9,000	>20,000	none	none	Caution
Sonalan 3EC	ethalfluralin *Elanco*	>10,000	> 2,000	moderate	moderate	Warning
Sonar	fluridone *Elanco*					
4AS		> 1,500	> 2,000	moderate	slight	Caution
5P (5%)		> 500	> 2,000	none	moderate	Caution
5SRP (5%)		> 500	> 2,000	none	moderate	Caution
Spike	tebuthiuron *Elanco*					
20P		> 500	> 2,000	none	moderate	Warning
40P		> 1,000	> 2,000	slight	moderate	Caution
80W		> 500	> 2,000	none	slight	Caution
80WSP		> 500	> 2,000	none	slight	Caution

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD50 Oral[c]	Acute LD50 Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Spike-Treflan 6G	tebuthiuron + trifluralin (2% + 4%) *Elanco*	> 500	> 2,000	moderate	moderate	Caution
Squadron 2.33L	pendimethalin + imazaquin (6:1) (2.0 + .33 lb) *American Cyanamid*	3,695	> 2,000	mild	severe	DANGER
Storm 4S	acifluorfen + bentazon (1.33 + 2.67 lb) *BASF*	> 1,470	> 2,000	none	severe	DANGER
Surflan 4AS	oryzalin *Elanco*	>10,000	> 2,000	slight	mild	Caution
Sutan + 6.7E	butylate *ICI Industries*	3,690	> 4,640	moderate	moderate	Caution
Sutazine +	butylate + atrazine					
18:6G	(18 + 6 lb)	> 5,000	> 5,000	none	none	Caution
6ME	(4.8 + 1.2 lb) *ICI Industries*	3,200	> 2,000	moderate	severe	DANGER-Corrosive
Tackle 2S	acifluorfen *Rhone-Poulenc*	1,370	> 2,000	moderate	severe	DANGER-Corrosive
Tandem 4EC	tridiphane *Dow*	1,668	1,000	moderate	severe	Warning
Team 2G	trifluralin + benefin *Elanco*	500	> 2,000	none	moderate	Caution
Telar 75DG	chlorsulfuron *DuPont*	2,341	> 3,400	none	mild	Caution
Thistrol 2S	MCPB *Rhone-Poulenc*	680		severe	severe-corrosive	Caution
Tordon 101* 2.5S	picloram + 2,4-D (.5 + 2.0 lb) *Dow*	2,598	> 2,000	moderate	moderate	Caution
Tordon 101R 1.3S	picloram + 2,4-D (.3 + 1.0 lb) *Dow*	> 5,000	> 3,980	moderate	moderate	Warning
Tordon K* 2EC	picloram *Dow*	> 5,000	> 2,000	slight	moderate	Caution
Tordon RTU 1.3S	picloram + 2,4-D (.3 + 1.0 lb) *Dow*	> 5,000	> 3,980	moderate	moderate	Warning

(See footnotes on first page of table.)

Trade name and formulation[a]	Generic name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Treflan	trifluralin					
4EC	*Elanco*	> 500	> 2,000	moderate	moderate	Warning
4MTF		> 5,000	> 2,000	moderate	moderate	Caution
5G		> 500	> 2,000	none	moderate	Caution
5EC		> 500	> 2,000	moderate	moderate	Caution
Tri-Scept	imazaquin + trifluralin (1:6)					
3EC	(.43 + 2.6 lb) *American Cyanamid*	4,330	> 2,000	mild	severe	DANGER
Tupersan	siduron					
50WP	*DuPont*	7,500	> 5,500	none	mild	Caution
Turbo§	metribuzin + metolachlor					
8EC	(1.45 + 6.55 lb) *Mobay*	849	> 2,000	slight	slight	Caution
Turflon D	triclopyr + 2,4-D					
3EC	(2 + 1 lb) *Dow*	1,792	1,796	mild	slight	Caution
Velpar	hexazinone					
90WSP	*DuPont*	860	> 5,278	none	moderate	Warning
2L		6,887	> 7,500	none	severe	DANGER
2RP		6,887	> 7,500	none	severe	DANGER
ULW (75G)		1,200	> 2,000	none	moderate	DANGER
Weedar 64	2,4-D dimethylamine					
3.8S	*Rhone-Poulenc*	1,150	1,530	mild	severe-corrosive	DANGER-Poison and corrosive
Weedar 64A	2,4-D diethanolamine					
3.8S	*Rhone-Poulenc*	2,576	> 2,000	mild	severe-corrosive	DANGER-Corrosive
Weedone 2,4-DP	dichlorprop (2,4-DP)					
4EC	*Rhone-Poulenc*	1,955	2,200	none	moderate	Caution
Weedone LV4	2,4-D ester					
3.8E	*Rhone-Poulenc*	1,375	> 2,000	mild	mild	Caution
Weedone 170	dichlorprop					
3.7E	+ 2,4-D *Rhone-Poulenc*	> 2,000	> 2,000	none	mild	Caution
XL	benefin + oryzalin					
2G	(1% + 1%) *Elanco*	3,750	> 2,000	slight	moderate	Caution

(See footnotes on first page of table.)

GENERIC AND TRADE NAMES OF HERBICIDES

Generic name	Trade name(s)	Generic name	Trade name(s)
acifluorfen	Blazer	bromacil	Hyvar
	*Galaxy		*Krovar
	*Storm		
	*Tackle	bromoxynil	Buctril
			*Buctril + atrazine
alachlor	*Ala-Scept		
	Arena	butylate	Genate Plus
	*Bronco		Sutan +
	*Bullet		*Sutazine +
	*Cannon		
	Confidence	chloramben	Amiben
	*Freedom		
	Judge	chlorimuron	*Canopy
	*Lariat		Classic
	Lasso		*Gemini
	Saddle		*Lorox Plus
	Stall		*Preview
ametryn	Evik	chlorsulfuron	Telar
amitrole	Amitrol-T	clomazone	Command
	Amizol		*Commence
asulam	Asulox	clopyralid	*Curtail
atrazine	AAtrex	cyanazine	Bladex
	Atrafine		*Extrazine II
	Atrazine		
	*Bicep	2,4-D	*Banvel 720
	*Buctril + atrazine		*Crossbow
	*Bullet		*Curtail
	*Extrazine II		*Tordon 101
	Griffex		*Tordon 101R
	*Laddok		*Tordon RTU
	*Lariat		Weedar 64
	*Marksman		Weedar 64A
	*Prozine		Weedone LV4
	*Ramrod/atrazine		*Weedone 170
	*Sutazine +		(many others)
benefin	Balan	dalapon	Dalapon 85
	*Team		Dowpon-M
	*XL		
		2,4-DB	Butoxone
bensulide	Betasan		Butyrac 200
	Prefar		Butyrac Ester
			*Rescue
bentazon	Basagran		
	*Galaxy	2,4-DP	(see dichlorprop)
	*Laddok		
	*Storm	DCPA	Dacthal

*Formulated mixture with additional active ingredient(s).

GENERIC AND TRADE NAMES OF HERBICIDES

Generic name	Trade name(s)
dicamba	Banvel *Banvel 720 *Marksman
dichlobenil	Casoron
dichlorprop (2,4-DP)	Weedone 2,4-DP *Weedone 170
diclofop-methyl	Hoelon
diphenamid	Enide
diquat	Aquaquat Diquat
diuron	Karmex *Krovar
DPX-L5300	*Harmony Extra
DPX-M6316	*Harmony Extra Pinnacle
endothall	Aquathol Endothal Hydrothal
EPTC	Eptam Eradicane Eradicane Extra Genep
ethalfluralin	Sonalan
fenoxaprop	Acclaim Option Whip
fenuron TCA	Dozer
fluazifop	Fusilade 2000
fluridone	Sonar
flurprimidol	Cutless
fosamine	Krenite
fomesafen	Reflex
glyphosate	Accord *Bronco Kleenup Ranger Rodeo Roundup
hexazinone	Velpar
imazapyr	Arsenal Contain
imazaquin	*Ala-Scept Scepter *Squadron *Tri-Scept
imazethapyr	Pursuit *Pursuit Plus
isoxaben	Gallery *Snapshot
lactofen	Cobra
linuron	*Gemini Linex Lorox *Lorox Plus
MCPB	Thistrol
MCPP	(see mecoprop)
mecoprop (MCPP)	Chipco Turf (many turf mixtures)
methazole	Probe
metolachlor	*Bicep Dual Pennant *Turbo
metribuzin	*Canopy Lexone *Preview *Salute Sencor *Turbo

*Formulated mixture with additional active ingredient(s).

GENERIC AND TRADE NAMES OF HERBICIDES

Generic name	Trade name(s)
metsulfuron	Ally
	Escort
MSMA	Arsonate
napropamide	Devrinol
naptalam	Alanap-L
	*Rescue
norflurazon	Solicam
oryzalin	*Snapshot
	Surflan
	*XL
oxadiazon	Ronstar
oxyfluorfen	Goal
paraquat	Gramoxone Extra
	Gramoxone Super
pendimethalin	Prowl
	*Prozine
	*Pursuit Plus
	*Squadron
picloram	*Access
	Tordon
prometon	Pramitol
pronamide	Kerb
propachlor	Ramrod
	*Ramrod/atrazine
quizalofop	Assure
sethoxydim	Poast
	Poast Plus
siduron	Tupersan
simazine	Aquazine
	Princep
	Sim-trol
sulfometuron	Oust
tebuthiuron	Spike
	*Spike-Treflan
terbacil	Sinbar
triclopyr	*Access
	*Crossbow
	Garlon
tridiphane	Tandem
trifluralin	*Cannon
	*Commence
	*Freedom
	*Salute
	*Spike-Treflan
	*Team
	*Treflan
	*Tri-Scept

*Formulated mixture with additional active ingredient(s).

Factors Affecting Herbicide Persistence

W. Curran

Herbicides are applied to the soil in hopes of obtaining season-long weed control. It is desirable for the chemicals to control weeds during the season of application, but they should not remain to affect subsequent crop growth. The length of time that a herbicide remains active in the soil is called "soil persistence" or "soil residual life." Anything that affects the disappearance or breakdown of herbicides will affect persistence. Many factors determine the length of time herbicides persist. Most factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. These categories strongly interact with one another.

Herbicides vary in their potential to persist in the soil. Some herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, pigment inhibitors, imidazilinones, and certain plant growth regulators. Table 1 lists several common herbicides in these groups. Table 2 lists the soil persistence of some common herbicides.

SOIL FACTORS

The soil factors affecting herbicide persistence fit into three categories: physical, chemical, and microbial. Soil composition is a physical factor that measures the relative amounts of sand, silt, and clay (the soil texture) and the organic-matter content of the soil. Chemical properties of the soil include pH, cation exchange capacity (CEC), and nutrient status. The microbial aspects of the soil environment include the type and abundance of soil microorganisms present.

Soil composition affects phytotoxicity and persistence through adsorption, leaching, and volatilization. Generally, soils high in clay or organic matter or both have a greater potential for carryover because of increased adsorption to soil colloids with a corresponding decrease in leaching and loss through volatilization. This "tie-up" results in decreased initial plant uptake and herbicidal activity. Therefore, more herbicide is held in reserve to be released later, potentially injuring susceptible future crops.

Some herbicides, principally the triazines (atrazine, propazine, and simazine) are particularly affected by soil pH, an important part of the soil chemical makeup. Lesser amounts of these herbicides are adsorbed or held to soil colloids at higher soil pH, so they remain in the soil solution. Herbicides in the soil solution are available for plant uptake. Chemical breakdown and microbial breakdown, two major herbicide degradation processes, are often slower in higher pH soils. So although decreased adsorption of triazine herbicides occurs in higher pH soils, there is also less breakdown activity.

Therefore, these herbicides are more available for plant uptake for a longer period of time on higher pH soils. Certain members of the sulfonylurea group (chlorsulfuron and chlorimuron) can also persist in higher pH soils because of decreased rates of chemical breakdown. Soil pH has little effect on the persistence of other herbicides.

Research shows that various nutrients and cations in the soil affect both herbicide activity and degradation. The CEC, which is principally a function of clay type and organic-matter content, is directly involved in herbicide adsorption. Some herbicides are more available in the presence of certain cations, whereas others may be tied up and therefore unavailable. The literature indicates that there is much variation in the effect that cations and nutrients can have on herbicide activity and breakdown, depending on soil composition, nutrient type and concentration, and the chemistry of the herbicide.

Soil microorganisms are partially responsible for the breakdown of many herbicides. The type of microorganisms and their relative amounts will determine how quickly decomposition occurs. Soil microbes require certain environmental conditions for optimum growth and utilization of any pesticide. Factors that affect microbial activity are temperature, pH, oxygen, and mineral nutrient supply. Usually, a warm, well-aerated, fertile soil with a medium soil pH is most favorable for microorganisms and hence herbicide breakdown.

CLIMATIC FACTORS

The climatic variables involved in herbicide breakdown are moisture, temperature, and sunlight. Herbicide degradation rates generally increase with increased temperature and soil moisture because both chemical and microbial decomposition rates increase under higher temperature and moisture. Cool, dry conditions slow down herbicide degradation, and as a result, carryover potential is greater. If winter and spring conditions are wet and mild, the likelihood of herbicides to persist is less.

Sunlight is also an important factor in herbicide degradation. Photodecomposition, or decomposition by light, has been reported for many herbicides. The dinitroanilines (trifluralin, pendimethalin, and ethalfluralin) are sensitive to light degradation. They may be lost when surface applied if they remain for an extended time period without rainfall. Therefore, degradation would be accelerated on very sunny days. This sensitivity to light and loss by volatility are primary reasons for soil incorporation.

HERBICIDAL PROPERTIES

Finally, the chemical properties of a herbicide affect its persistence. Important factors include water solubility, vapor pressure, and susceptibility to chemical and microbial alteration or degradation.

The water solubility of a herbicide helps to determine its leaching potential. Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away or carried to susceptible plant rooting zones. Herbicide leaching is determined not only by its water solubility, but also by its ability to adsorb to soil particles. Additionally, soil texture and available soil water affect herbicide leaching. Herbicides that are low in water solubility, that are strongly adsorbed to soil colloids, and that exist in dry soils are less likely to leach and have a greater potential to persist.

The vapor pressure of a herbicide determines its volatility. Volatility is the process whereby herbicides change from a liquid or solid to a gas. Volatility increases with temperature. Volatile herbicides such as the thiocarbamates (EPTC, butylate) must be incorporated immediately to avoid gaseous losses. These herbicides are less likely to persist than herbicides with a low vapor pressure.

Herbicides may be rapidly decomposed by microorganisms in the soil if the right kind and number of microorganisms are present and if soil conditions are favorable for their growth. However, herbicides vary greatly in their susceptibility to microbial decomposition. For example, microbial decomposition of 2,4-D occurs very quickly in the soil, whereas atrazine degradation is slow.

Chemical decomposition is dependent not only on the chemistry of the herbicide (how susceptible it is to chemical breakdown), but also on soil and climatic factors. Chemical breakdown of a herbicide involves reactions such as hydrolysis, oxidation, and reduction. The occurrence of these reactions and the rate at which they take place will vary with soil type and climatic conditions. These reactions along with microbial degradation are important processes in the decomposition of herbicides.

Avoiding Herbicide Persistence in Subsequent Crops

There are several ways to avoid herbicide carryover problems. First, always apply the correct rate of any pesticide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. In order to accomplish this goal, accurate acreage determination, accurate chemical measurement, proper sprayer calibration, and uniform application are essential. Always read the label before applying any herbicide.

The method and time of application can be important in avoiding herbicide carryover. Some herbicides must be incorporated. However, if herbicides have the potential to persist longer than desired, those applied preplant incorporated will more likely remain longer than those surface applied without incorporation. Incorporating the herbicide makes it less susceptible to loss by volatilization and photodecomposition. In addition, the herbicide is immediately exposed to charged soil particles and possibly tied up through adsorption. Decreased environmental losses (volatilization and photodecomposition) and increased adsorption both favor herbicide carryover. Banded herbicide applications can reduce carryover potential because less total herbicide is applied in a band than if it is broadcast. Postemergence and late applications may have a greater potential for being present in next year's crop. However, unlike soil applications, postemergence treatments are intercepted by both crop and weeds; therefore, less herbicide reaches the soil. This may reduce the residue concentration the following year.

The amount of tillage will affect herbicide persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till, which leave crop residue on the soil surface, also tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect susceptible crops. In addition, higher rates of herbicides are often used in reduced tillage systems to maximize weed control and adjust for greater amounts of crop residues. If a herbicide carryover problem already exists, some tillage to dilute the chemical may help.

Herbicide combinations may reduce the risk of carryover problems. By tank mixing two or more herbicides, we might reduce application rates of those products that potentially cause problems and broaden our weed control spectrum at the same time.

Herbicides may interact with one another or with other pesticides and enhance crop injury when they are applied in the same or in consecutive years. For example, a soybean crop may tolerate a certain level of atrazine carryover. However, if another photosynthetic inhibitor such as metribuzin is applied to soybeans after atrazine-treated corn, injury is more likely.

Plants absorb herbicides from the soil in which they are growing. Persistence may be less if the herbicide is metabolized or broken down by the plant or if the plant containing the absorbed herbicide is harvested and removed from the field. Plant extraction of the herbicide from the soil may not be an important factor under most situations, but it has been used in some situations to help remove persistent herbicides from treated soils.

Finally, the selection of a tolerant rotational crop or variety will help minimize carryover problems. Quite often, economics will dictate crop rotation; however, there are varietal differences that might affect the likelihood of serious crop injury. For example, some soybean varieties are more sensitive to the triazine herbicides than others and should not be used if the potential for triazine injury exists. Also, as a general rule, smaller seeded crops and varieties have a greater potential for injury from persistent herbicides than do larger seeded species.

If herbicide carryover is suspected, a soil chemical test or biological assay can help determine if harmful levels of herbicide residue are present. Chemical analysis can be expensive, so a biological bioassay may be more feasible. Either can help you to determine if herbicide residues exist and if a tolerant crop or variety should be planted into a problem area. (See section on testing for herbicide residues.)

Many variables interact in predicting herbicide persistence. Factors involved in the degradation of herbicides include many soil, climatic, and herbicidal properties. The potential for herbicide carryover problems can be reduced by using the appropriate rates and the accurate timing of proper application methods. The use of selective tillage, herbicide combinations, and tolerant crops and varieties can also help reduce the risk of crop injury.

Table 1. Herbicide Families with Their Persistent Members

S-triazines atrazine hexazinone (Velpar) propazine (Milogard) simazine (Princep)	*Phenylureas* diuron (Karmex) fluometuron (Cotoran)	*Sulfonylureas* chlorsulfuron (Glean) chlorimuron (Classic) sulfometuron (Oust) DPX-R9360 (Accent primisulfuran (Beacon)
Dinitroanalines benefin (Balan) ethalfluralin (Sonalan) oryzalin (Surflan) pendimethalin (Prowl) trifluralin (Treflan)	*Uracils* bromacil (Hyvar-X) terbacil (Sinbar)	*Plant Growth Regulators* picloram (Tordon) fenac (Fenatrol)
Others bensulide (Prefar, Betasan) diphenamid (Enide) fluridone (Brake, Sonar) norflurazon (Zoriel, Solicam) sodium borates tebuthiuron (Spike) clomazone (Command)	*Imidazolinones* imazaquin (Scepter) imazethapyr (Pursuit) imazapyr (Arsenal)	

Table 2. Soil Persistence of Some Common Herbicides[a]

1 month	1 to 3 months	3 to 12 months	>12 months
2,4-D	acifluorfen (Blazer/Tackle)	atrazine	bromacil (Hyvar-X)
glyphosate (Roundup)	alachlor (Lasso)	benefin (Balan)	chlorsulfuron (Glean)
MCPA	ametryn (Evik)	bensulide (Prefar, Betasan)	picloram (Tordon)
paraquat (Gramoxone)	bentazon (Basagran)	bromoxynil (Buctril)	prometon (Pramitol)
	butylate (Sutan/Genate)	chlorimuron (Classic)	sodium borate
	chloramben (Amiben)	diphenamid (Enide)	sulfometuron (Oust)
	cyanazine (Bladex)	diuron (Karmex)	Tebuthiuron (Spike)
	DCPT (Dacthal)	ethalfluralin (Sonalan)	
	EPTC (Eptam/Eradicane)	fomesafen (Reflex)	
	linuron (Lorox)	fluridon (Brake, Sonar)	
	metolachlor (Dual)	clomazone (Command)	
	metribuzin (Sencor/Lexone)	hexazinone (Velpar)	
	naptalam (Alanap)	imazaquin (Scepter)	
	propachlor (Ramrod)	imazethapyr (Pursuit)	
	siduron (Tupersan)	norflurazon (Zoriel, Solicam)	
	terbutryn (Igran)	oryzalin (Surflan)	
	vernolate (Vernam/Reward)	pendimethalin (Prowl)	
		pronamid (Kerb)	
		propazine (Milogard)	
		simazine (Princep)	
		terbacil (Sinbar)	
		trifluralin (Treflan)	

[a]Herbicides applied at labeled Illinois use rates.

Testing for Herbicide Residues

W. Curran, M. McGlamery, E. Knake, D. Pike, and D. Anderson

Herbicides vary in their potential to persist in soil. Those herbicides that can persist to the next season may injure subsequent crops and need to be monitored closely. Two methods used to determine if harmful herbicide residues might exist are a soil chemical test done at a laboratory and a bioassay done either in the suspect field or in a warm, sunny indoor location, such as a greenhouse. These tests help predict potential herbicide residue problems so that the grower can make better decisions about crop rotation, herbicide selection, planting date, and other cultural practices.

With the lab analysis or indoor bioassay, proper sampling of the soil is the first step. The soil sampling procedures for submitting a soil for laboratory analysis and for conducting an indoor bioassay are similar. These guidelines should be followed.

SOIL COLLECTION AND PREPARATION

1. Collect representative soil samples from the suspect field. Samples should be collected in early to midspring or prior to planting. Take samples from several locations in the field. For the bioassay or laboratory analysis, take 15 to 20 soil cores and combine them to make a composite sample. This sample should represent no more than 15 to 20 acres. Enough areas must be sampled to avoid missing locations with high herbicide residue content. **Take separate samples from areas where excessive residues are suspected such as sprayer turnaround points and end rows.** Do not mix these samples with the others. Sample the soil to a 6-inch depth and divide the samples into 0- to 3- inch and 3- to 6-inch sections for greater accuracy. Be sure to mark on the bags the depths from which the samples came. Approximately 8 pounds of soil (4 quarts) are needed for each bioassay and 2 pounds of soil (about 1 quart) for each laboratory analysis.

2. Sample an area that is not suspect for use as a "check" soil. This soil may be taken from a nearby fence row, garden, or other untreated area. Keep this soil sample separate from the others. Many laboratories require a check soil.

3. Submit the samples to the laboratory as soon as possible after sampling. If bioassays are to be performed, they should be run on the soil samples as soon as possible after they have been obtained from the field. If samples cannot be assayed immediately, then store the soil in a cold environment, such as a refrigerator or freezer that is not used for food. If samples are stored in a warm environment, herbicide residue may decrease with time.

BIOASSAY

The bioassay can help predict potential crop injury. These tests are inexpensive and can be done with a few simple supplies. The bioassay will not provide an exact measure of the amount of herbicide residue present in the soil, but it may indicate whether enough residue is present to harm a sensitive crop.

Field Bioassay

A field bioassay is conducted by planting one or more strips of a sensitive species in a suspect field. This procedure can be done in the fall or spring, but it is more accurate if performed closer to the planting of the intended crop. Plants for bioassay must have enough time to grow and develop symptoms of injury if herbicide residues are present before planting the desired crop. The strips should be planted in several locations if possible and include an area that is most suspect and an area that can serve as a check. Choose an appropriate species for the bioassay, such as one of the more sensitive ones listed in this paper. Include several species of differing sensitivity for greater accuracy.

Indoor Bioassay

The procedure for conducting an indoor bioassay will vary depending on what herbicide residue is of concern. For the indoor bioassay, the procedures for soil collection and preparation, however, are the same.

1. For the indoor bioassay, take the samples and allow them to air dry if needed until they can be worked readily. Do not overdry the samples. If the soil is cloddy, crush the clods into small pieces (the size of a pea or smaller). If the soil contains a high amount of clay, the addition of coarse sand (50 percent by volume) will improve its physical condition. If sand is added, thoroughly mix it with the soil.

2. Tin cans, milk cartons, or cottage cheese containers are appropriate containers in which a bioassay can be conducted. Punch holes in the bottom of the containers to allow water drainage. Fill two or more containers (a set) with soil from each sample. Additional containers will increase the accuracy of the test. Place the soil samples from the 0- to 3-inch depth in one set of containers, and in another set, place the soil obtained from the 3-to 6-inch depth. Follow this procedure for the composite sample and the sample taken from areas where excessive residues are expected. In addition, fill a final set of containers with the check soil.

Triazine Residues

For suspected carryover from triazine herbicides such as atrazine and Princep (simazine), an oat plant bioassay works best. Place about 15 oat seeds in each container of soil and cover the seeds with approximately 1 inch of soil. Wet the soil with water but do not saturate it.

Place the containers in a warm location (70° to 75°F) where they will receive ample light. Sunlight is essential for the development of the plant as well as for inducing symptoms of triazine injury. The container should be watered when necessary.

Injury symptoms should become apparent within 10 to 14 days after planting. Triazine injury is characterized by chlorosis (yellowing) followed by necrosis (browning) of the leaf tissue. Injury symptoms will start at the leaf tip and develop toward the base of the leaf. Smaller amounts of herbicide residue may only stunt the plant. Therefore, it is essential that a comparison with the plants in the check soil be made.

If injury appears on the oats, then enough herbicide residue may be present to injure a susceptible crop. Planting a more tolerant crop is suggested. In general, the order of susceptibility to triazine herbicides is:

Triazine: Ryegrass > Alfalfa > Oats > Wheat > Soybean > Sorghum > Corn

DNA Residues

If residues from dinitroaniline (DNA) herbicides, such as Treflan (Trifluralin), Surflan (oryzalin), or Prowl (pendimethalin) are suspected, a different assay technique is used. A sorghum or corn root bioassay is relatively quick and easy to perform.

Wrap sorghum or corn seed in a moist paper towel and store them at room temperature for 2 to 3 days. This procedure allows the seed to imbibe water and germinate. Once the seed has germinated, carefully place 3 to 5 seeds into containers with the suspect soil and check soils. Cover the seed with soil to a depth of approximately 1 inch, and leave them for 10 to 14 days, depending on the air temperature. Water the plants as needed but do not saturate the soil.

At the end of the 7- to 14-day period, carefully remove the plants and observe root formation. DNA herbicides inhibit root development. Symptoms include stunted plants, stubbed roots, inhibited root-hair development, thickened hypocotyls on broadleaf species, and leaves that fail to unroll. If the plants in the suspect soil display any of these symptoms in comparison to the check plants, then DNA residues may be present at concentrations high enough to injure susceptible crops. In general, the order of susceptibility to DNA herbicides is:

DNA: Annual Rye > Oats > Sorghum > Corn > Wheat > Alfalfa > Soybean

Imazaquin, Imazethapyr, or Chlorimuron Residues

Imazaquin, the active ingredient in Scepter and a component of Squadron, Tri-Scept, and Ala-Scept; imazethapyr, the active ingredient in Pursuit and a component of Pursuit Plus; and chlorimuron, the active ingredient in Classic and a component of Preview, Canopy, Lorox Plus, and Gemini have the same mode of action in sensitive plants. These herbicides affect root and shoot growth and development. Symptoms of plant injury include inhibited root development, stunted plants, and interveinal chlorosis or leaf striping. Therefore, a sorghum or corn root bioassay performed according to the procedure outlined for suspected DNA residue is appropriate. Corn is more sensitive to imazaquin and sorghum is more sensitive to imazethapyr and chlorimuron. In addition to root observations, look for stunted shoot growth and interveinal chlorosis or yellowing. Bioassay plants should be grown for 14 to 21 days. The order of crop susceptibility to imazaquin, imazethapyr, and chlorimuron is as follows:

Imazaquin: Rape > Alfalfa = Corn = Sunflower > Sorghum > Oats > Wheat > Soybean

Imazethapyr: Rape > Sorghum > Sunflower > Oats > Wheat > Alfalfa = Corn > Soybean

Chlorimuron: Rape > Alfalfa > Sunflower > Sorghum > Corn > Oats > Wheat > Soybean

Command (Clomazone) Residues

Command and Commence inhibit the production of photosynthetic pigments in susceptible plants and, therefore, cause plants to emerge lacking green color so they are white or albino. Lower levels of Command residue may appear as a chlorosis or mild bleaching of the plants. Oats or wheat can be used to detect Command residues using the same procedure as outlined above for detecting triazine residues. Bioassay plants should be grown for 10 days to 2 weeks. Susceptible plants that are exposed to significant levels of Command residues will be white, while untreated or tolerant plants will be green. Keep in mind that oats and wheat are usually more susceptible than corn to injury from Command. The order of susceptibility to Command residues is as follows:

Command: Oats = Wheat = Alfalfa > Sunflower = Sorghum = Corn > Soybean

Other Residues

Bioassays can be made for other herbicides using similar techniques. If the mode of action of a specific herbicide is known, then we can develop a procedure for detecting the herbicide. For example, if the herbicide is a root meristematic inhibitor, that is, it stops cell division in the roots, then a root bioassay is the appropriate test. If the herbicide inhibits photosynthesis, then injury symptoms will first appear in the leaves. Choose a species that is moderately susceptible to the suspected herbicide and always include a check soil. Wheat and oats are very good indicator plants for many herbicides but may be more sensitive than the desired crop. Include several different species in the bioassay to give a better range of susceptibility. The desired crop is always a good bioassay plant to be included.

LABORATORY ANALYSIS

Laboratory analysis involves extracting the herbicide from the soil with the use of specialized equipment to detect very small amounts of herbicide. The amount of herbicide is expressed in parts of herbicide per million parts of soil (ppm). Parts of herbicide per million parts of soil can be transposed into pounds of herbicide per acre if we assume that an acre (A) of soil weighs 1,000,000 pounds in the top 3 inches and 2,000,000 pounds in the top 6 inches.

Thus, for a soil sample taken to a 6-inch depth, 1 ppm = 2 lb/A of residue.

For a soil sample taken to a 3-inch depth, 1 ppm = 1 lb/A of residue.

So a lab reporting 0.2 ppm atrazine means that there is 0.2 pound of atrazine per acre if the samples were taken to a 3-inch soil depth, and 0.4 pound per acre if taken to a 6-inch soil depth.

The location and concentration of the chemical will depend on what herbicide is used, the soil type, whether the ground was tilled, and the amount of rainfall since application. In most medium-textured soils (silt loams, silty clay loams, sandy clay loams), the herbicide remains primarily in the top 3 inches unless there was excessive rainfall, the ground was plowed, or the herbicide was deeply incorporated. If the soil has a high sand content (coarse texture), then herbicide leaching may be greater. Movement of the herbicide out of the surface soil zone by tillage or by rainfall decreases the likelihood of crop injury. The risk of injury is increased when the herbicide residue is concentrated in the top 3 inches rather than distributed throughout the 6-inch soil depth. Therefore, it is best to sample the 0- to 3-inch and 3- to 6 inch sections separately.

Whether we use parts per million or pounds of active ingredient of herbicide, translating these units of measure into potential crop injury is difficult. Many variables affect crop susceptibility or tolerance, including soil type, crop sensitivity, and environmental conditions after planting. Crop injury is more likely on more coarsely textured soils or under cool, wet weather conditions. Additionally, high soil pH increases the likelihood of triazine or chlorimuron injury.

The following general guidelines are provided, although the reader is cautioned that crop injury may still occur below these levels:

General Guidelines for Interpreting Laboratory Analysis

Herbicide	Safe level (ppb)*	Crop
Triazine	150-250	soybean
	< 100	alfalfa, oats, wheat
Dinitroanaline	100-200	corn
	200-300	wheat
Clomazone	50-200	corn
	15-100	wheat, alfalfa
Imazaquin	2-10	corn
	10-30	wheat
Imazethapyr	10-30	corn
	4-15	sorghum
Chlorimuron	1-2	corn
	2-5	wheat

*Due to differences in herbicide availability from the soil, "safe" values for herbicide residues differ according to soil type. Low range values are for coarsely textured soils with low levels of organic matter; higher range values are for finely textured soils with higher levels of organic matter. (1 ppm = 1,000 ppb)

Laboratories may differ in available tests and in the price of the analysis. The cost can range from $20 to $200 per sample or herbicide analysis. Most laboratories can analyze a sample and have the results in 5 to 7 days. Contact your county Extension adviser for more information on laboratory selection.

CORRECTING FOR HERBICIDE RESIDUES

If the lab test or bioassay indicates that a potential herbicide residue problem exists, several steps can be taken.

1. First select a tolerant crop or variety. This selection will depend on what herbicide is of concern. Check current herbicide labels for more information on crop tolerance.

2. Till to help dilute the herbicide in a problem field.

3. Plant the field of corn last. Delaying the planting allows more time for the herbicide to break down.

4. If the triazine herbicides or chlorimuron (Classic, Canopy, Gemini, Preview, or Lorox Plus) are suspect, be sure to check the soil pH and adjust your management practices accordingly.

In summary, a bioassay or laboratory test is not 100 percent accurate in predicting herbicide residue problems. Crop response to herbicide residue depends on a number of factors, including species and variety, soil type, and environmental conditions after planting. Therefore, predicting crop injury is often difficult. However, using a soil chemical test or biological assay can help in deciding whether a potential problem exists and in choosing the appropriate crop or variety.

Factors Affecting Crop Injury Due to Herbicides

W. Curran

Correct diagnosis of crop injury requires an accurate investigation of the present symptoms and as much information as possible about the history of the area showing symptoms. Herbicides are sometimes blamed for crop injury caused by fungal, bacterial, or viral pathogens, nutrient deficiencies or excesses, insect damage, or adverse weather conditions that cause similar or "look-alike" symptoms. Therefore, it is helpful for the field person to have detailed information on each injury situation as well as plant and soil samples for evaluation before attempting to identify the cause of injury.

When present, herbicide injury frequently occurs in distinct patterns within the field caused by faulty equipment or misapplication of the herbicide. Signs indicating faulty application of herbicides include streaks of injury resulting from improper incorporation, overlapping of the spray pattern, improper nozzle size and spacing, or improper boom height. Injury occurring at the field ends may result from failure to shut off the sprayer when making turns. Injury symptoms may follow lines of water movement or appear where changes in soil type, organic matter content, pH level, and field topography occur.

Look for spray or drift patterns and compare adjacent untreated fields with the area showing injury symptoms. Also, compare the response of susceptible weed species and watch for symptoms caused by insects, disease, mechanical damage, wind, drought, and other environmental conditions.

FACTORS CONTRIBUTING TO HERBICIDE INJURY

Limited Selectivity

Most herbicides are classified as selective herbicides. This means they control or kill some species of plants without seriously injuring others. However, the margin of selectivity or safety is often narrow, meaning the difference between the amount that will kill the weed and the amount that can cause crop injury may be very small.

The margin of safety can often be increased and the risk of injury reduced by carefully selecting the rates most appropriate for the specific soil and weed species and using no more herbicide than necessary. If you know the soil texture and organic matter content for herbicides applied to the soil and properly identify the weeds for timely postemergence applications, weed control can be improved and crop injury avoided.

Crop safety can be improved by using herbicide combinations with reduced rates of individual components, lessening the likelihood of crop injury from any one herbicide. The addition of additives such as crop oil concentrate, nonionic surfactant, fertilizer solutions, or other adjuvants to postemergence sprays may increase or decrease weed control or crop tolerance. Therefore, careful consideration should be given to selecting the appropriate additive.

Faulty Application

Herbicides require precision in application. Select rates carefully and calibrate equipment accurately. Also, be sure to apply the herbicide accurately and uniformly. Some ways to avoid faulty application are:

1. Be sure all nozzle tips are the same size and their spray patterns are uniform.

2. Adjust the boom height to give a uniform spray pattern.

3. Be sure the herbicide is properly mixed and agitated in the spray tank.

4. Use some type of marking system to avoid skips and overlaps.

5. Maintain proper speed.

6. When incorporating, use equipment that will give uniform distribution of the herbicide. One pass with a field cultivator or finishing disks is often inadequate.

7. With postdirected sprays, it is important to minimize contact of the herbicide with the crop.

8. Shut the boom off when turning on field ends.

9. Do not overlap or double applications on field ends.

Environmental Factors

Even when extreme care is used, adverse weather conditions may still alter the effect of the herbicide from what is normally expected.

Conditions favorable for rapid emergence and vigorous growth of the crop can reduce the risk of herbicide injury. Planting too deep may mean that the emerging shoot or growing point of the seedling will be in contact with the soil herbicide longer, increasing the risk of injury.

Under cool, wet conditions, the metabolism of the plant is reduced and the plant grows more slowly. Herbicide taken into the plant may not be detoxified as rapidly as normal and injury may result.

Under very warm, humid conditions, the herbicide may enter the plant more rapidly, and if crop tolerance is limited, injury may result. Hot, dry conditions can also influence the effect of the herbicide by putting additional stress on the plant.

Secondary stresses such as plant disease, insects, poor physical condition of the soil, and adverse weather can all reduce the vigor of the plant. Such conditions may magnify the effect of the herbicide on the plant.

Genetic Susceptibility

Differences in plant susceptibility to herbicides are due in part to morphological and physiological plant differences. For example, leaf hairiness or pubescence may affect the entry of a herbicide. Also, the plant physiology or chemistry inside plants often differs. This enables some species to detoxify certain herbicides while others are not able to do so. Such morphological and physiological differences exist not only for different species but also within species. This explains why certain varieties or genetic lines show greater or lesser tolerance to some herbicides.

Herbicide Drift

Herbicides may injure nearby desirable plants when they move outside the target area where application has been made. There are two types of herbicide drift: particle drift, where fine spray particles move through air at application time; and vapor drift, when the herbicide changes from a liquid phase to a gaseous or vapor phase due to the volatility of the compound. Vapor drift can occur at application or for several days following application.

Particle drift can be reduced by using higher volumes of carrier, lower application pressures, and nozzle types that do not deliver very fine or small droplets, by applying herbicides when wind conditions are low, and by using spray additives that reduce drift. Vapor drift can be reduced by selecting formulations of herbicides that are less volatile. For example, the amine formulation of 2,4-D is less volatile than the ester formulation. Also, environmental conditions such as temperature and humidity affect volatility and movement. Volatile herbicides should not be applied when temperatures are high (for example, above 85°F).

Herbicides can also move from treated areas in surface water or blowing soil to adjacent areas. One risk of herbicide movement is from treated waterways or roadside ditches where water may move to adjacent crop areas.

Herbicide Carryover

Herbicides vary in their potential to persist in soil. Herbicides that persist to the next season may injure subsequent crops and need closer monitoring. A number of factors affect how long a herbicide persists. These factors include the chemical properties of the herbicide and the amount applied; soil properties such as texture, organic matter, and pH; and climatic conditions following herbicide application. If herbicide residues persist into the following cropping season, factors such as genetic susceptibility of the crop and the environmental factors discussed previously may determine whether or not crop injury occurs. Refer to "Factors Affecting Herbicide Persistence" and "Testing for Herbicide Residues" for additional information on herbicide carryover.

1990 Condensed Plant Disease Management Guide for FIELD CROPS

You must be certified as a pesticide applicator to use restricted-use pesticides. See your county Extension adviser in agriculture for information.

The best way to ensure the success of a disease management program is to adapt it to the diseases expected and to use integrated disease control measures. Among these measures are the use of resistant varieties, crop rotations, fungicides, nematicides, and suggested agronomic practices. The success of any one or all of these measures may depend on how carefully you scout your crops. Because periodic crop scouting increases the likelihood that disease controls will be applied properly, it can help prevent both loss through disease and unnecessary use of pesticides.

Specific information for the control of the important diseases of corn, soybeans, wheat, and alfalfa can be found in the following issues of *Report on Plant Diseases:*

No. 123: "Winter Wheat Disease Management Program"
No. 212: "Illinois Corn Disease Management Program"
No. 308: "Alfalfa Disease Management Program"
No. 507: "Illinois Soybean Disease Management Program"
No. 1001: "Seed Treatments for Field Crops"

These and other issues of *Report on Plant Diseases* are available from the Department of Plant Pathology, University of Illinois, N533 Turner Hall, 1102 S. Goodwin, Urbana, IL 61801.

FEDERAL AND STATE LAWS RESTRICTING PESTICIDE APPLICATION

The U.S. Environmental Protection Agency (EPA) is classifying pesticides for "general" or "restricted" use. Anyone applying a restricted-use pesticide, whether "commercial" or "private," must be certified.

Commercial applicators include not only persons applying restricted-use pesticides for hire but also government personnel, chemical company representatives, and others involved in demonstrational, regulatory, and public health pest control. Certification as a commercial applicator requires passing a written examination administered either by the Illinois Department of Agriculture or the Illinois Department of Public Health.

Private applicators who use restricted-use pesticides "for the purpose of producing any agricultural commodity on property owned or rented by [the applicator] or as exchange labor (no compensation) on the property of another must also be certified, either by attending an educational training program or by passing an examination."

Educational training programs for farmers (private applicators) and commercial pesticide applicators are conducted by the Illinois Cooperative Extension Service to prepare persons for certification. The actual certification and the issuing of permits or licenses are handled by the Illinois State Department of Agriculture.

DISEASES

ALWAYS READ THE LABEL BEFORE USING A PESTICIDE

The chemical names used in this circular may be unfamiliar to you. They are the common, coined chemical names and are not capitalized (for example, benomyl). Trade names are capitalized (for example, Benlate). Because of the large number of products, formulations, combination products, and application methods, only the coined chemical names are used in tables in this text. Consult your local county Extension adviser or agrichemical dealer for appropriate products containing the active ingredient named in the tables.

Before making any pesticide application, refer to the most recent label for rates, harvest intervals, and other information. All materials in this circular are correct at the time of publication (October 1989). However, labels may change with regard to crops approved, rates, time of application, and other important information. Therefore, it is very important to have a copy of the most recent label before applying any material.

FUNGICIDE APPLICATION

At present, aircraft are the best vehicles for applying fungicides to agronomic crops. Some aircraft may not be equipped or calibrated to do this job. It is therefore important to select an aerial applicator who is familiar with disease control and whose aircraft has been properly calibrated for uniform, thorough coverage of all aboveground plant parts. With the equipment now available, a reasonable job of applying fungicides requires a minimum of 5 gallons of water carrier per acre. Superior coverage may be obtained with more water, but the cost

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
CIRCULAR 1231-90 (revised annually) October 1989

may be prohibitive. Conversely, a lower volume (under 3 to 4 gallons per acre) gives correspondingly poorer control. Five gallons of water can be applied uniformly using approximately 30 to 70 properly spaced nozzles, depending on the aircraft. The nozzles should be D-8 to D-12, hollow cone, with No. 45 or No. 46 cores. The final decision on nozzle number, size, swath width, and placement depends on the air speed, pressure, and volume desired. Droplet size is also important. Ideally, droplets should be 200 to 400 microns in size for thorough and uniform coverage.

ADJUVANTS

When it is compatible with the product label, add a spray adjuvant (surfactant) to the spray mix. Adjuvants are suggested for use when you spray to help disperse fungicides and improve coverage. They are especially helpful for corn and small grains. Some commonly available surfactants are: Bio 88, BioFilm, Regulade, Plyac, Triton AG-98, Triton B-1956, Triton CS-7, Chevron Spray Sticker, Chevron Spreader, X-77, NuFilm P, NuFilm 17, and DuPont Spreader Sticker (liquid) spreader sticker.

NEMATICIDE APPLICATION

Granular nematicides/insecticides registered for use on corn, sorghum, and soybeans may be used as in-furrow or band treatments, depending on the product label. In general, band applications have given more consistent control than have in-furrow applications. Follow the manufacturer's suggestions on incorporation. Nematicides should be used only where soil analysis shows an economic problem. They are not designed to replace crop rotation and the use of resistant crop varieties in a management program. Successful nematode management is based upon a combination approach which may include pesticides. However, pesticides alone will not provide adequate control and may produce additional environmental problems. Follow soil sampling instructions in *Report on Plant Diseases* No. 1100, "Collecting and Submitting Soil Samples for Nematode Analysis." This publication is available from Extension Plant Pathology, N-533 Turner Hall, 1102 S. Goodwin Ave., Urbana, IL 61801.

Trade Names. A more complete list of trade names can be found in *Report on Plant Diseases* No. 1002, "Fungicides, Disinfectants, Grain Preservatives, Surfactants, and Soil-Disinfesting Chemicals." This publication is available from Extension Plant Pathology, University of Illinois, N-533 Turner Hall, 1102 S. Goodwin, Urbana, IL 61801.

Table 1. Condensed Disease-Control Recommendations for Field Crops

Crop	Diseases	Fungicide or nematicide	Comments
Alfalfa	Seed rots and seedling blights	captan, thiram, metalaxyl	Seed treatment is not usually necessary with high-quality seed.
	Bacterial wilt, Phytophthora root rot		Resistance should be strongly considered when choosing a variety.
	Leafspots, spring blackstem, and anthracnose		Cut forage in a timely manner to maximize yields and minimize leaf loss. Grow adapted resistant varieties.
	Crown and root rots		Maintain proper fertility and soil pH. Avoid cutting or grazing during the last 5 to 6 weeks of the growing season. Control insect pests.
	Verticillium wilt		Seed treatment with thiram is suggested to prevent seed transmission. This disease will only be a problem in stands that are more than 3 years old. Resistant varieties should also be considered.
	Sclerotinia white mold		Spring planting, deep and clean plowing, using 3- to 4-year rotations with nonlegume crops, and avoiding excessively lush growth may help. Chemical controls are not available. The variety Cimarron is reported to be moderately resistant.
Barley	Seed rots, seedling blights, loose smut	carboxin, thiram, captan, maneb, PCNB, mancozeb	Seed treatment is strongly suggested. Carboxin is required for loose smut control.
	Helminthosporium leaf blight, Septoria leaf blotch	mancozeb	Apply when disease conditions warrant. Apply when plants are in the late tillering to jointing stage; repeat at 7- to 10-day intervals. Do not make more than 3 applications. Do not apply within 26 days of harvest.
	Barley yellow dwarf virus		Plant winter barley after the fly-free date and spring barley as early as possible.
Clover	Anthracnose diseases		Grow adapted resistant varieties.
	Crown and root rots		Same as for alfalfa.
	Seed rots and seedling blights		Same as for alfalfa.
Corn	Seed rots and seedling blights	captan, maneb, carboxin, thiram, mancozeb, TCMTB	Sow injury-free, plump seed in soils at 50°F or above. Prepare the seedbed properly and place herbicide, fertilizer, insecticide, and seed correctly. Note: fungicide plus insecticide seed treatments are commonly used.

Table 1. (continued)

Crop	Diseases	Fungicide or nematicide	Comments
Corn (cont.)	Helminthosporium leaf blights northern leaf blight northern leaf spot southern leaf blight Helminthosporium leaf blight	zineb, mancozeb	Plant resistant hybrids. Apply 2 to 4 sprays at 10-day intervals starting when disease appears. Fungicide control is justified only when significant disease occurs less than 2 weeks after tasseling. Use a spreader sticker. Fungicide applications are generally economically feasible only in seed-production fields. Do not apply within 40 days of harvest. Do not feed fodder or forage to livestock.
	Common rust and southern rust	zineb, mancozeb	Same as for Helminthosporium leaf blights.
	Stewart's disease		Plant resistant hybrids or use insecticides to control flea beetles when necessary.
	Goss's bacterial wilt and leaf blight		Plant resistant hybrids. Clean plowdown and 2-year crop rotations also give control. Use clean plowdown only where erosion will not be a problem.
	Anthracnose, Physoderma brown spot, eyespot, gray leaf spot, yellow leaf blight		Plant resistant or tolerant hybrids. Practice crop rotation or clean tillage where soil-erosion considerations allow.
	Crazy top and sorghum downy mildew		Plant resistant or tolerant hybrids. Improve drainage in affected area. Control wild cane to reduce sorghum downy mildew inoculum.
	Virus diseases		Plant resistant hybrids. Control johnsongrass to reduce overwintering source of MDMV and MCDV.
	Stalk rots *Diplodia* charcoal *Gibberella* *Nigrospora* *Fusarium* anthracnose		Plant hybrids with good stalk rot resistance and stalk strength. The use of a nitrogen stabilizer may be helpful where nitrogen loss is expected. Maintain adequate phosphorus and potassium fertility for the rate of nitrogen used. Control corn borers and corn rootworms. Scout fields at 30- to 40-percent moisture for lodging potential. Walk a zig-zag pattern through the field pushing random plants about 5 inches from the vertical. If more than 10 to 15 percent lodge, schedule the field for early harvest.
	Storage molds *Penicillium* spp. *Aspergillus* spp.	propionic acid, isobutyric acid, acetic acid, or mixtures of these	Grain treated with an acid grain preservative can be used only for animal feed. Store undamaged corn at 15 to 15.5 percent moisture from fall until spring, then dry to 13 percent for long-term storage. Grain damaged by field molds, insects, etc., should be dried to 13 to 13.5 percent moisture at harvest. Watch stored grain for heating, a musty odor, crusting, or other signs of storage mold activity. Control stored grain insects. Make sure combine is adjusted to avoid damage to grain. Remove fines and foreign material before storage.
	Nematodes root-lesion needle dagger spiral lance	carbofuran, ethoprop, terbufos	Use nematicidal rates of these materials only where soil tests indicate economic populations of nematodes. Use crop rotation where appropriate. For needle nematode control avoid small grains in rotations and control grass weeds. More than 1 species of root lesion nematodes may be present in a field. Species identification should be made before selecting rotation crops.
Oats	Seed rots and seedling blights, loose smut and covered smut	captan, maneb, carboxin, thiram, PCNB, TCMTB	Seed treatment is strongly suggested for control of smut diseases.
	Barley yellow dwarf		Grow resistant varieties. Plant susceptible varieties as early in the spring as possible.
	Crown rust		Plant resistant varieties. Fungicides applied for *Septoria* and *Helminthosporium* will also aid in crown rust control.
	Helminthosporium leaf spot, Septoria leaf blotch	mancozeb	Spray when disease is present and weather conditions favor disease development. Start applications at tillering to jointing stage. Make a second application 10 days later. A third application is permissible but may be uneconomical. Do not apply within 26 days of harvest.
Sorghum	Seed rots, seedling blights, and smuts	captan, thiram, PCNB, maneb	Fungicide seed treatment is strongly suggested. Plant in soils at 60°-65°F or above.
	Other diseases		Plant resistant or tolerant hybrids. Diseases other than the smuts have not been important in Illinois.
	Nematodes	aldicarb, carbofuran	Apply only where soil analysis indicates an economic problem.

Table 1. (continued)

Crop	Diseases	Fungicide or nematicide	Comments
Soybeans	Seed rots and seedling blights (primarily Pythium, Phytophthora, Rhizoctonia)	captan, carboxin, thiram, PCNB, thiabendazole, metalaxyl	Plant high-quality seed germinating greater than 70 percent in a cold germination test. Seed treatment is recommended where (1) seed of poor quality due to fungal infection must be planted; (2) delays in emergence are anticipated; (3) seed is planted to produce seed; (4) reduced seeding rates are used; and (5) seed is planted into heavy crop (reduced or no-till). Plant in soils at 55°F or above.
	Charcoal rot		Plant full-season varieties as early as possible. Avoid excessive seeding rates and maintain optimal fertility. Deep fall plowing may be beneficial where soil-erosion concerns allow.
	Brown stem rot		Rotate, using 2 years of corn in fields where disease has been damaging. The varieties BSR 301, BSR 302, BSR 201, BSR 101, and Chamberlain have moderate resistance.
	Sclerotinia white mold		Rotate with nonlegume crops. Plant moderately resistant varieties in fields where disease has been present before.
	Phytophthora root rot	metalaxyl	Plant varieties with race-specific or field resistance (tolerance). Race-specific resistance will provide immunity to specific races. However, in some areas, races of the Phytophthora fungus are present that can attack this type of resistance. Varieties with field tolerance are resistant after two sets of trifoliate leaves develop. However, they are very susceptible to the seedling blight phase of the disease. Therefore, varieties with field tolerance should be protected in the seedling stage with metalaxyl fungicide applied as a seed treatment. Varieties with field tolerance can be protected for 6 to 8 weeks after planting by using metalaxyl as a band or furrow treatment at planting.
	Soybean cyst nematode, root lesion nematode	aldicarb, carbofuran, fenamiphos	Maintain proper soil fertility. Rotate with nonhost crops such as corn, small grains, red clover, alfalfa, and with SCN-resistant soybean varieties. An example of a rotation following SCN-damaged soybeans: corn followed by an SCN-resistant variety followed by corn. Monitor SCN populations by taking soil samples after third year. If populations are below the level for damage, use as high-yielding susceptible soybean variety to reduce the buildup of a different race. If populations are above the damage level, plant a nonhost crop and repeat soil sampling. Nematicides are suggested only where (1) crop rotations are not possible and (2) resistant varieties are not readily available. Aldicarb has given the most consistent control; applied in-furrow, it has given control equal to higher rates applied in bands. Both aldicarb and carbofuran can be applied in-furrow. See *Report on Plant Diseases* No. 501 for more information. There are no soybean varieties resistant to root-lesion nematodes. Consequently, crop rotation and nematicides are the most practical approaches for controlling lesion nematodes. These control approaches are discussed in *Report on Plant Diseases* No. 1103, entitled "Lesion Nematodes."
	Sudden death syndrome		No direct control methods have been identified. Controlling the soybean cyst nematode may be beneficial. Early maturing or early planted beans appear more susceptible.
	Pod and stem blight, anthracnose, stem canker, Septoria brown spot, Cercospora leaf blight, and purple seed stain	benomyl, thiabendazole, thiophanate-methyl	Suggested for use where disease conditions warrant (see Table 2). Two applications are suggested for maximum yield and seed quality. A single late application at higher labeled rates will improve seed quality. Use pod tests to determine the need for late applications. Do not graze or feed treated soybean vines to livestock. Observe days to harvest limit which varies by product.
Wheat	Seed rots, seedling blights, loose smut, and bunt (stinking smut)	carboxin + thiram, carboxin (planter-box) plus maneb + HCB, captan + carboxin, or maneb + thiabendazole	Seed treatment is strongly suggested. Higher labeled rates of carboxin are required for bunt control. Only carboxin controls loose smut.
	Leaf rust, Septoria leaf blotch, Septoria glume blotch, Helminthosporium leaf blight, stem rust, and Pyrenophora tan spot	mancozeb, triadimefon, benomyl, mancozeb, thiabendazole	Apply fungicide when disease conditions warrant. Do not make more than 3 applications of mancozeb and do not apply within 26 days of harvest. Triadimefon is limited to 16 oz. of material per season and has a 21 days to harvest restriction. Rotational crops (corn, soybeans, sorghum, and small grains) cannot be planted for 35 days following the last application of triademefon. Benomyl is limited to 3 applications per season with a 26 days to harvest restriction. Thiabendazole will reduce Septoria glume blotch. Do not make more than 2 applications per season. Plant resistant varieties. Do not allow livestock to feed or graze on treated plant materials.

Table 1. (continued)

Crop	Diseases	Fungicide or nematicide	Comments
Wheat (cont.)		propicanazole	One application per season is permitted at emerging flag leaf stage (Feekes Stage 8). Do not apply after this stage to avoid possible illegal residues. Do not graze or feed livestock treated forage or cut the green crop for hay or silage. After harvest, the straw may be used for bedding or feed.
	Powdery mildew	triadimefon, propicanazole	Plant resistant varieties. Check with your Extension adviser for chemical control recommendations.
	Virus diseases wheat streak mosaic wheat soilborne mosaic barley yellow dwarf mosaic wheat spindle streak mosaic		Plant resistant or tolerant varieties. Plant after the fly-free date. Control volunteer wheat in and around production fields.
	Take-all		Plant after the fly-free date. Use ammonium form of nitrogen fertilizer. Use crop rotations of 2 to 3 years between wheat crops where possible.

FUNGICIDE GUIDELINES

Seed Treatments

The greatest benefits of fungicide seed treatments will be found (1) where low seeding rates are used; (2) where seed must be used that is of poor quality because of fungal infection; and (3) where seed is planted in a seedbed in which delays in germination or emergence are likely.

Fungicide seed treatments are not a substitute for high-quality seed and will not improve the performance of seed that is of low quality due to mechanical damage or physiological factors. Treated seed of low quality will not produce stands and/or yields equal to untreated high-quality seed. Therefore, only high-quality seed should be considered for planting.

The following checklist for soybean seed treatments (Table 2) is designed to assist in determining the need for seed treatments, especially for control of damping-off fungi. Selection of the proper seed treatment is very important because of the specificity of certain fungicides for controlling only Phytophthora and Pythium.

Foliar Treatments

Foliar fungicide treatments may reduce losses from Septoria brown spot, Cercospora leaf blight (purple seed stain), anthracnose, pod and stem blight, and stem canker. These diseases are most damaging when the weather is warm (70° to 80°F) and wet from early pod fill to maturity. Foliar sprays of fungicides may increase yields 10 to 15 percent, increase seed quality, and reduce disease losses when such fields are planted to soybeans the following year. The use of fungicides should be based on expected disease severity. The six diseases just listed will *not* be as severe in cool, dry seasons and where adequate rotations have been used.

Table 2. Soybean Seed Treatment Checklist for Reducing Early Season Stand Losses Due to Damping-Off from Pythium and Phytophthora Fungi

Risk factors	Point value if answer is yes
Rainfall for the 7-day period before planting was:	
Below normal	2
Normal	1
Above normal	4
Seedbed preparation was:	
Conventional tillage	1
Rough surface (conservation tillage)	2
No-till	4
Germination at time of planting is less than 85 percent in a warm test or less than 70 percent in a cold test (such seed should be discarded if at all possible)	3
Previous soybean stand in field was reduced by damping-off or Phytophthora root rot	4
Level of resistance to Phytophthora root rot is:	
Susceptible	2
Tolerant	4
Resistant to one or more races	1
Expected rainfall for 96 hours following planting is:	
Lower than normal	1
Normal	1
Above normal	3
Low areas of field remain flooded for 48 hours following 1 inch of rainfall	4
Seeding rate is less than 55 pounds per acre	3
Field is planted to double-crop soybeans	3

TOTAL POINTS AND SUGGESTIONS

Less than 7 points: seed treatment will probably not be beneficial.

Seven to 15 points: seed treatment may be beneficial if weather conditions do not favor rapid germination and growth.

Greater than 15 points: seed treatment will be beneficial to stand development.

Based on seven years of research data, yields have been increased by an average of 4.7 bu/A (range 1.2-13.4), and seed quality has been increased by an average of 10.7 percent (range 0-42.5 percent) by the use of foliar fungicides.

The checklist in Table 3 can be used at early bloom to determine whether fungicide controls for the six diseases mentioned previously should be used. A key factor in this checklist is the presence of black specks (pycnidia) on fallen petioles. Only brown, fallen petioles should be assayed, and more than two-thirds to three-fourths of these petioles should show pycnidia. If growers use the checklist and apply fungicides correctly, maximum benefits should be achieved. Less than optimal benefits will be achieved if fungicides are applied incorrectly or if disease severity does not warrant spraying.

DISEASE REACTIONS OF FIELD CROP VARIETIES RECOMMENDED FOR ILLINOIS

Disease reactions may vary from one locality to another and from year to year, depending on what physiologic races of the pathogens are present. For the latest information on suggested crop varieties, consult your county Extension adviser or the Department of Agronomy, University of Illinois, W-201 Turner Hall, 1102 S. Goodwin, Urbana, IL 61801.

We wish to thank the following for their assistance in preparing the tabular material given below: F.L. Kolb, Department of Agronomy, University of Illinois, Urbana-Champaign; E.D. Nafziger, Department of Agronomy, University of Illinois, Urbana-Champaign; D.W. Graffis, Department of Agronomy, University of Illinois, Urbana-Champaign; C.D. Nickel, Department of Agronomy, University of Illinois, Urbana-Champaign; G.E. Pepper, Department of Agronomy, University of Illinois, Urbana-Champaign; W.L. Pedersen, Department of Plant Pathology, University of Illinois, Urbana-Champaign.

Table 3. Checklist to Determine Whether Foliar Fungicide Application Should Be Made to Soybeans

Risk factors	Point value if answer is yes
Rainfall, dew, and humidity up to early bloom and pod set are:	
Below normal	0
Normal	2
Above normal	4
Soybeans were grown in the field last year	2 to 3
Chisel-plow, disk, or no-till was used	1
Pycnidia (black specks) are visible on fallen petioles, and Septoria brown spot is obvious on the lower leaves	2
Early maturing variety (not full-season)	1 to 2
Soybeans are to be used or sold for seed	6
Yield potential is better than 35 bushels per acre	2
Seed quality at planting time is less than 85 percent germination in a warm test	1
Other conditions that favor disease development (weather forecast with a 30-day period of greater-than-normal rainfall and a field history of disease)	1 to 3

Note: If the total point value is 15 or more, application will probably mean increased yields and higher seed quality.

Soft Winter Wheat

Variety	Recommended area of state[a]	Stem rust	Leaf rust	Loose smut	Septoria	Powdery mildew	Soil-borne mosaic	Barley yellow dwarf	Wheat spindle streak
Argee	N	R	S	MR		MS	R	MR	
Arthur 71	N,C,S	R	S	MS	MS	MS	R	MS	MS
Auburn	N,C,S	R	R	MR	R	MR	R	MS	MS
Becker	N,C,S		MR		MS	S	MR		R
Caldwell[b]	N,C,S	R	MR	MR	MS	MR	MR	MR	MS
Cardinal[b]	C,S	MS	MR						
Clark	C,S		MS		MR	MR	R		
Dynasty	N,C,S		R			MR			
Hart	N,C,S	S	S	R	MR	VS	R	MR	MR
Pike	N,C,S	S	S	MR	MS	S	MR	MR	MS
Roland	C,S	R	S	MS	S	MS	R	MS	MR
Scotty	C,S	R	MR		MR	R	R	MS	
Tyler	S	S	S			R	R	MR	

Notes: Several private varieties have high yield potentials and are widely planted. Growers should contact seed company representatives for information on disease resistance.

In this table, average disease reaction is indicated as follows: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; VS = very susceptible; Blank = no information or disease is not important.

[a] Area of Illinois where variety is recommended: N = northern; C = central; S = southern.

[b] Moderate resistance to take-all.

Grasses

Variety	Endophyte level	Helminthosporium and rust diseases	Alkaloid level	Maturity	Winter hardiness
Orchardgrass					
Benchmark		..		Early	H
Boone		..		Early	H
Crown		MS (Rust)		Medium Late	EH
Dart		MS (Rust)		Medium	MH
Dawn		..		..	..
Hawk		MS (Rust)		Medium Early	H
Ina		..		Medium	H
Juno		MR		Early	EH
Napier		..		Medium Late	H
Pacific		MS (Rust)		Medium Early	..
Pennlate		..		Late	SH
Pennmeade		..		Medium	SH
Potomac		..		Early	MH
Ranco		MS (Rust)		Late	H
Sterling		..		Medium Early	H
Reed canarygrass					
Castor		..	..	Early	EH
Flare		..	..	Medium	H
Palaton		T	Low	Medium Early	EH
Vantage		..	Moderate	Medium	H
Venture		..	Low	Medium Early	EH
Bromegrass, smooth					
Barton		..		Medium	H
Baylor		..		Medium	H
Blair		..		Medium	H
Bravo		..		Medium	H
FS Beacon		..		Medium	H
Fox		..		Medium	H
Lincoln		..		Medium	H
Rebound		..		Medium	H
Sac		..		Medium	H
Jubilee		MS		Medium Early	H
Tall fesuce					
Fawn	Varies	..	..	Late	MH
Forager	Low	..	..	Late	MH
Johnstone	Low[a]	..	Low	Medium	MH
Kenhy	Low	..	Medium	Medium	MH
Kenwell	Varies	..	Medium	Medium	MH
Ky-31	Varies	..	Medium	Medium	MH
Martin	Low	HR	..	..	MH
Mozark	Low	MR	..	..	MH
Timothy					
Itasca		..		Early	H
Mariposa		..		Medium	H
Mohawk		..		Late	H
Pronto		..		..	H
Richmond		..		Early	H
Timfor		..		..	H

Note: In this table, average disease reaction is indicated as follows: MS = moderately susceptible; MR = moderately resistant; HR = high resistance; and T = tolerant. For varieties that do not offer resistance to all Helminthosporium and rust diseases, the specific diseases for which these varieties offer resistance appear in parentheses. The degree of winter hardiness in this table is as follows: SH = some hardiness; MH = moderately hardy; H = hardy; and EH = excellent hardiness. A blank under the columns for the level of endophytes and the level of alkaloids indicates that this category does not apply to the given variety.

[a] Certified as low by seed standards.

Soybeans

Variety	Suggested area of the state[a]	Phytophthora rot[b]	Bacterial pustule	Powdery mildew	Pod and stem blight	Soybean cyst nematode (races 3 and 4)		Purple seed stain	Downy mildew	Sclerotinia white mold
Beeson 80	N	R-1-3,7-9	S	MR	S	S	S	S	S	
BSR 101[c]	N	R			MS	S	S	MR		
BSR 201[c]	N,C	R			MS	S	S			
Burlison	N,C	R-1-9				S	S			
Cartter	C,S	S				R	R			
Century 84	N,C	R-1-9	S		S	S	S	S	MS	S
Chamberlain[c]	C,S	R				S	S			
Corsoy 79	N,C	R-1-3,7-9	S			S	S		MS	
Egyptian	S	S		VS	S	R	R	S		
Essex	S	S	R			S	S		MS	
Fayette	C,S	S	R			R	R	MS		
Forrest[de]	S	MR	R	MR		R	S	S		
Gnome 85	N,C	R-1-9	R		S	S	S			S
Hack	N,C	R			S	S	S			
Hardin	N	R	S			S	S			
Harper 87	C,S	R-1-9	R			S	S			
Hobbit 87	C,S	R-1-9	R		S	S	S			
Pella 86	C,S	R-1-9	R			S	S		S	S
Pennyrile	S	S				S	S	S		
Pershing	S	S				S	S			
Pixie	S	S				S	S			
Preston	N,C	S				S	S			
Pyramid	S	S				R	R			
Resnik	C,S	R-1-9				S	S			
Ripley	S	S				S	S			
Sherman	C,S	S			S	S	S			
Spencer	S	S				S	S			
Union	S	S				S	S		R	MR
Williams 82	C,S	R-1-9				S	S		S	
								S		
					MS					

Notes: Growers should contact individual seed companies for information on disease resistance of private varieties.
In this table, average disease reaction is indicated as follows: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; VS = very susceptible; Blank = no information. R-1,2 indicates resistant (R) to the pathogens indicated by the race numbers.
[a] Area of Illinois where variety is suggested: N = northern; C = central; S = southern.
[b] Races 1 and 2, except where other races are indicated.
[c] Resistant to brown stem rot.
[d] Also resistant to wildfire, target spot, reniform nematode, and root-knot nematode.
[e] Also resistant to race 1.

Barley

Variety	Recommended area of state[a]	Stem rust	Leaf rust	Loose smut	Covered smut	Septoria	Powdery mildew	Barley yellow dwarf	Barley stripe mosaic	Spot blotch	Net blotch	Helminthosporium stripe	Scald
Spring													
Larker	N	MR	S	S	S	S	S	MS	S	S	MS		S
Manker	N	MR	S	S	S	S	S	MS	S	MR	MR		S
Winter													
Barsoy	C,S	MS	S	S			MR	S	S		MS	S	S
Pike	C,S	MS	S	S			MR	S	S		MR	MR	S
Wysor	C,S		R			MS	R	MR			MS		R

Note: In this table, average disease reaction is indicated as follows: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; Blank = no information.
[a] Area of Illinois where variety is recommended: N = northern; C = central; S = southern.

Oats

Variety	Recommended area of state[a]	Stem rust	Crown rust	Smuts	Barley yellow dwarf	Septoria
Spring						
Don	N,C,S	S	R	R	MR	MS
Hazel	N,C,S	S	R	S	R	MS
Lang	N,C,S	MS	S	MS[b]	MR	MS
Larry	N,C,S	MS	S	MS	MR	MS
Noble	N,C,S	MS	S	R	MR	MS
Ogle	N,C	MS	S	MS	MR	MS
Otee	N,C,S	MS	S	MS	R	MS

Note: In this table, average disease reaction is indicated as follows: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; Blank = no information.

[a] Area of Illinois where variety is recommended: N = northern; C = central; and S = southern.

[b] Susceptible to new races of smut fungi.

Red Clover

Variety	Powdery mildew	Northern anthrac-nose	Southern anthrac-nose	Viruses
Arlington	R	R		MR
Florex	MR	R		R
Florie	R	R	R	R
Kenland	S	S	R	S
Kenstar	S	S	R	MR
Marathon		R	MR	
Mega	R	R	R	
MorRed	R	R	MR	
Redland	R	MR	R	S
Redland II	R	R	R	
Reddy		MR	MR	
Ruby	S	R	R	

Note: In this table, average disease reaction is indicated as follows: R = resistant; MR = moderately resistant; T = tolerant; S = susceptible; Blank = no information.

Alfalfa

Variety	Verticil-lium wilt	Bacterial wilt	Fusarium wilt	Common leaf spot	Lepto leaf spot	Spring black stem	Anthrac-nose	Phytoph-thora root rot	Winter hardiness[a]
Action	R	R					HR	R	MH
Americana Acclaim	MS	R	R	MR			MR	MR	H
Americana PH2121		HR	R	MR			MR	R	MH
Anstar		R	MR				R	S	MH
Apollo		R		MR	MS	MS	MS	R	H
Apollo II	MR	R	R				MR	R	MH
Apollo Supreme	R	R					R	R	
Armor		R	R				MR	R	MH
Arrow	R	HR	HR				MR	HR	H
Bell Ringer	R	R	MR				HR	MR	MH
Blazer		R	R				MS	R	MH
Challenger		R	MR				R	R	MH
Chief	R	HR	R				R	HR	MH
Cimarron	MS	HR	HR	MR			HR	MR	MH
Classic		HR							H
Conquer		R		S			MR	MR	MH
Crown	R	R	R				R	R	MH
Dart	R	HR	HR				R	HR	MH
Decathlon	MT	HT	T				MT	MT	MH
DeKalb Brand 120		HR	MR				MR	R	H
DeKalb Brand 135	HR	R	R		HR		MR	MR	Mh
Drummor		R	MR				MR	R	H
Dynasty	R	HR	R				MR	R	MH
Eagle	MR	HR	R				R	MR	H
Edge	R	R					HR	R	MH
Elevation	MR	R	R				MR	MR	MH
Embro A-54		R		MR			. .	. .	H
Endure	R	R	R				MR	R	H
Epic		R	R				S	R	MH

Alfalfa (continued)

Variety	Verticillium wilt	Bacterial wilt	Fusarium wilt	Common leaf spot	Lepto leaf spot	Spring black stem	Anthracnose	Phytophthora root rot	Winter hardiness[a]
Funk's G-2852	R	HR	R				HR	R	MH
Funk's G-7730		HR	R				MS	HR	H
Garst 624	S	MR	MR				MR	MR	H
Garst 629	MR	MR	R				MR	MR	MH
Garst 630	MR	HR	R				MR	MR	
Garst 636	R	HR	R				MR	R	MH
GT 58	S	MR	HR				MR	MR	MH
Hi-phy		R						R	H
Honeoye		MR							MH
Husky		R	R				R	MR	MH
Impact	R	HR	HR				MR	R	MH
Jubilee		R	R				R	R	MH
Magnum		HR					MR	T	MH
Magnum +	MS	R					MR	R	MH
Mercury		R	HR				MR	HR	H
Milkmaker		R	HR				MR	MR	MH
Oneida		R						R	H
Oneida VR	R	R					S	MR	MH
Peak	MS	R					MS	R	H
Perry		R					T	S	MH
Pioneer Brand 526	S	HR	MR				MS	MS	VH
Pioneer Brand 5432	R	HR	HR				S	MR	H
Pioneer BR531	S	R	R				S	S	
Raidor		R	MS				R		MH
Riley	S	HR					HR	S	MH
Saranac	S	MR	S					S	H
Saranac AR	S	MR		MR	MS	MS	R	S	H
Shenandoah		R	R	MR		MR	R	R	MH
Sparta	R	R	MR				S	MR	H
Surpass	R	R	R				MR	R	H
Thorobred		R						R	H
Thunder		HR	HR				MR	R	MH
Total	MS	R	R	T			MR	R	MH
Trident	MS	MR	HR				MR	HR	LH
Vancor		R	MR				R	MR	H
Vernal	S	R		MS	MS	MS	S	S	H
Vernema	MR	MR					MS	MS	MH
Voris		HR	MR				MS	MR	H
Voris A-77		HR					HR	MS	H
WL-221		R	MR	R	R		MR		H
WL-225	R	HR	R				MR	HR	H
WL-315		HR	HR				MR	MR	MH
Wrangler	MS	R	R				MS	HR	H

Note: In the table, average disease reaction is indicated as follows: HR = highly resistant; R = resistant; MR = moderately resistant; HT = highly tolerant; MT = moderately tolerant; T = tolerant; MS = moderately susceptible; S = susceptible; and blank = no information.

[a] Winter hardiness is based primarily on autumn growth ratings: VH = very hardy; H = hardy; MH = moderately hardy; LH = low winter hardiness.

This circular was prepared by H.W. Kirby, M.C. Shurtleff, D.M. Eastburn, and D.I. Edwards, Extension Plant Pathologists with the Department of Plant Pathology, University of Illinois at Urbana-Champaign. The suggestions given in this circular are revised annually.

1990 Disease Management Guide for Commercial Vegetable Growers

THE SUCCESSFUL CONTROL OF VEGETABLE DISEASES requires an integrated program that includes the use of resistant varieties, crop rotation, balanced soil fertility, weed and insect control, and proper crop culture as well as the proper selection and timing and method of application of fungicides, bactericides, or nematicides. Economical control depends on establishing an overall disease management system for the entire farm. Keeping careful records of the crops that have been planted, the problems encountered, and the pesticides used is important.

The information in this circular is updated annually. The grower should also consult the current versions of Circular 897, *Insect Pest Management Guide: Commerical Vegetable Crops and Greenhouse Vegetables,* and Circular 907, *Weed Management Guide for Commercial Vegetable Growers,* as well as Circular 1174, *Vegetable Varieties for Commercial Growers,* which contain information on disease resistance. Those circulars are revised each year.

Because many disease problems originate with seeds or transplants, growers should follow the seed treatment recommendations given in this circular and in Report on Plant Diseases No. 915, *Vegetable Seed Treatment,* or be sure to obtain planting material that is certified as disease free.

This publication presents the vegetable fungicide tolerances and application intervals for various crops as approved by the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA) as of September 1, 1989 to the best of our knowledge. The tables on the next two pages give the number of days between the last application at the normal rate and the harvest as well as other restrictions that will keep residues within the tolerances set by the FDA. Refer to current labels for information on rates, timing, and methods of application, as well as for information on followup crops and other restrictions.

The listing of a chemical as approved for use on a particular crop does not mean that the Illinois Cooperative Extension Service or Agricultural Experiment Station recommends the use of the chemical for that crop. Our specific recommendations for disease control are given in the table entitled "Condensed Recommendations on Disease Management . . ."

In some instances a tolerance has been set, but a definite interval has not been established. The absence of an interval for a particular crop in the listings does not necessarily mean that the fungicide may not be used on that crop. To ensure that the crop produced does not exceed the tolerance, the use of the fungicide would require a restriction such as "do not apply after first blooms appear" or "do not apply after edible parts form." This information appears on the product label.

In a few cases the interval and dosage have been established, but the allowable residue concentration has not been determined. Again, this does not mean that the fungicide may not be used on the crops for which it is labeled. It does mean, however, that until the tolerance is established, it must be considered as zero. These cases are reviewed each year, and some are cancelled when the chemical manufacturer supplies the EPA with additional data.

Growers must follow a program of disease control that will assure that the vegetables produced do not contain excessive fungicide residues. Vegetables marketed with residues exceeding the FDA tolerances may be injurious to consumers, may be confiscated, and may cause the grower to be brought to court.

Growers have nothing to fear from the law as long as they use fungicides and other pesticides according to the current label and only on the crops specified, in the amounts specified, and at the time specified. The prudent grower keeps a record of the products and trade names used, the percentage of active ingredients, dilutions, rates of application per acre, and dates of application.

This circular is revised each year. Be sure you are using the most recent copy.

Prepared by D.M. Eastburn and M.C. Shurtleff, Department of Plant Pathology

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE

Urbana, Illinois | Circular 1184-90 (revised annually) | October 1989

LIMITATIONS ON DAYS BETWEEN APPLICATION AND HARVEST AND OTHER RESTRICTIONS WHEN USING FUNGICIDES ON VEGETABLES IN ILLINOIS

Crop	Benlate[a]	Bravo[b]	Dyrene	maneb + zinc salt[c]	mancozeb[d]	Botran[f]
Asparagus	. .	. .	. .	A	A; root dip	. .
Beans (dry, lima, snap)	14, 28 on lima, B	7, (snap only) B; 42, (lima, dry)	. .	. .	. .	2, B
Beet, garden	. .	. .	. .	. .	. .	. .
Broccoli	. .	0	. .	. .	. .	. .
Brussels sprout	. .	0	. .	. .	. .	. .
Cabbage	. .	0	. .	. .	. .	. .
Cantaloupe (muskmelon and honeydew melon)	0	0	. .	. .	. .	. .
Carrot	4	0	. .	. .	. .	ph
Cauliflower	. .	0	. .	. .	. .	. .
Celery	7	7	0	. .	. .	. .
Chinese cabbage	. .	7	. .	. .	. .	. .
Corn, sweet and pop	. .	14, B[e]	. .	0, B	7, B	. .
Cucumber	0	0	. .	. .	. .	0
Eggplant	. .	. .	. .	. .	. .	. .
Endive, escarole	. .	. .	. .	. .	. .	14
Fennel	. .	. .	. .	. .	. .	. .
Garlic	. .	7	0	. .	. .	pp, ph
Kale, collard	. .	. .	. .	. .	. .	. .
Kohlrabi	. .	. .	. .	. .	. .	. .
Leek	. .	. .	. .	. .	. .	. .
Lettuce	. .	. .	. .	. .	. .	14
Mustard greens	. .	. .	. .	. .	. .	. .
Onion	. .	green, 14; dry, 7	0	0	7, D, pb	pp, ph
Parsley	. .	. .	. .	. .	. .	. .
Parsnip	. .	. .	. .	. .	. .	. .
Peas	. .	. .	. .	. .	. .	. .
Pepper	. .	. .	. .	. .	. .	. .
Potato, Irish	. .	0	0	0, C	0	14, B
Pumpkin	0	0	. .	. .	. .	. .
Radish	. .	. .	. .	. .	. .	. .
Shallots	. .	14	. .	. .	. .	. .
Spinach	. .	. .	. .	. .	. .	. .
Squash	0	0	. .	. .	. .	. .
Tomato	0	0	0	5, F	5	0
Turnip, rutabaga	. .	. .	. .	. .	. .	. .
Watermelon	0	0	. .	. .	. .	. .

NOTE: Numbers in the table indicate number of days between last application and harvest; 0 = up to harvest. Dots in a column indicate that the fungicide is not registered for use on that particular vegetable. Other abbreviations used in the table are as follows:

A = Postharvest application to ferns only or to young plantings that will not be harvested.
B = Do not feed treated tops or forage to livestock.
C = Do not use treated seed or seed pieces for feed or food.
D = Do not apply to exposed bulbs.
F = To avoid damage, do not use on tender young plants.
pb = Plant bed treatment.
ph = Postharvest spray or dip.
pp = Preplant soil treatment.

[a] Do not apply Benlate alone; always use in combination with mancozeb or other labelled protective fungicide such as Captan, Bravo, Dyrene, or maneb. Do not mix with Mertect or Topsin-M.
[b] Chlorothanonil is sold as Bravo 75WP, 500, 720, and 90DG. It is also sold in combination with metalaxyl as Ridomil/Bravo 81W and with copper and maneb as Bravo C/M.
[c] Maneb with zinc salt is sold as Dithane M22 Special, Maneb Plus, Maneb 4L Plus, and Manex Maneb F.
[d] Mancozeb is sold as Dithane M-45, Manzate 200, Manzate 200 Flowable, Dithane F-45, and Pencozeb.
[e] Do not apply if the crop will be used for processing.
[f] Dichloran is sold as Botran 75W.

Label registrations can change at any time. Thus, recommendations in this circular may become invalid. The user is encouraged to carefully read the entire, most recent label, and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

LABEL INFORMATION ON FUNGICIDES AND NEMATICIDES OF LESS GENERAL USE

Fungicide (tolerance)	Crops and use restrictions
Aldicarb (Temik 15G)	Nematodes, **Beans** (dry), **potato, sweet potato.**
carbofuran (Furadan 15G)	**Corn** (sweet and pop) — Nematodes. Apply in band or furrow at planting. **Cucumber, melons, squash, pumpkin** — incorporate into top 3 inches of soil.
Copper fungicides[b] tribasic copper sulfate (many trade names)	**Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, celery, cucumber, eggplant, honeydew melon, lettuce, muskmelon, onion, pea, pepper, potato, pumpkin, radish, spinach, squash, tomato, watermelon.**
copper sulfate (many)	**Beans, broccoli, cabbage, cantaloupe, cassaba melon, cauliflower, celery, cucumber, honeydew melon, muskmelon, Persian melon, potato, pumpkin, radish, squash, tomato, watermelon.**
copper ammonium carbonate (Copper-Count N)	**Beans, cabbage, cantaloupe, carrot, cassaba melon, celery, crenshaw melon, cucumber, honeydew melon, lettuce, muskmelon, pepper, Persian melon, potato, squash, tomato, watermelon.**
copper hydroxide (Champion, Kocide 101 and 606)	**Beans, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, celery, cucumber, eggplant, lettuce, muskmelon, onion, pea, pepper, potato, pumpkin, squash, tomato, watermelon.**
copper oxychloride sulfate (COCS, Copro 50, CS-56, Coxysul)	**Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cassaba melon, cauliflower, celery, crenshaw melon, cucumber, eggplant, honeydew melon, lettuce, muskmelon, onion, pea, Persian melon, potato, pumpkin, spinach, squash, tomato, watermelon.**
Bordeaux mixture (many trade names)	**Asparagus, beans, beets, broccoli, Brussels sprout, cabbage, carrot, cassaba melon, celery, collard, crenshaw melon, cress, cucumber, eggplant, honeydew melon, horseradish, kale, mustard, pepper, rape, rutabaga, spinach, muskmelon, Persian melon, potato, pumpkin, radish, squash, tomato, turnip, watermelon.**
Dikar	**Cantaloupe, cucumber, melon, summer squash** — 7 days[a].
dinocap (Karathane)	**Cantaloupe (muskmelon), cucumber, honeydew melon, pumpkin, squash, watermelon** — 7 days[a]. For control of powdery mildew only.
etridiazole (Terrazole, Truban)	Seed treatment: **Beans, peas.**
ethoprop (Mocap)	Nematodes. **Beans, cabbage, corn, cucumber, potato, sweet potato.**
fenamiphos (Nemacur 15G)	Nematodes. **Brussels sprout, cabbage, garlic,** and **okra.**
Iprodione[d] (Rovral)	**Beans**[c] — Sclerotinia. **Broccoli** — blackleg. **Carrot** — Alternaria and Cercospora leaf spots, no more than 8 applications. **Garlic** — white rot. **Head lettuce** — lettuce drop and bottom rot, no more than 3 treatments, 14 days[a]. **Onion** (dry) — Botrytis and Alternaria purple blotch, 7 days[a]. Root crops, cereal grains, soybeans, and tomatoes may be planted the next year. Garlic and leafy vegetables may be planted following treated lettuce.
metalaxyl (Apron 25WP)	Seed treatment for control of Pythium and Phytophthora damping-off and root rot on **beans, beets, dill, pea, lentils, okra,** and **edible soybeans.**
(Ridomil 2E)	*Bedding plants* to control Pythium damping-off — **Broccoli, cabbage, cauliflower, cucumber, lettuce, melons, spinach,** and **squash.** Apply 2-4 pints per acre as preplant broadcast in 50 gal. of water (1-2 fl. oz. or 2-4 tablespoons per 150 sq. yd. of bed in 2 gal. of water) before or at the time of seeding to the surface of the beds and lightly incorporate or follow with one-half inch sprinkler irrigation water.
	(Field use). **Asparagus** — Phytophthora crown and spear rot. **Beans** (all), **lentils, pea, soybeans** (edible). Pythium damping-off and root rot when used at 1 pint per 13,000 linear feet of row, either in-furrow or in a 7-inch band at planting. **Broccoli, cabbage, cauliflower** — Pythium damping-off and Phytophthora basal stem rot. Applications may be broadcast using 4 pints per acre, applied at planting in 20-50 gal. of water, or at 4-8 pints per acre, incorporated into the upper 2 inches. Seven-inch band applications at 2 pints per 13,000 linear feet of row are also labeled. **Cucumbers, melons, squash** — Pythium damping-off and cottony leak. Applications can be in a 7-inch band over the row at planting or at 4-8 pints per acre broadcast, using 20-50 gal. of water. Broadcast applications may be incorporated to the 2-inch depth. **Onions, leafy vegetables, lettuce** (head), **spinach.** Pythium damping-off. Apply either broadcast or banded at planting. Follow label directions. **Pepper, eggplant** — Pythium damping-off, Phytophthora crown rot, 7 days[a]. **Tomatoes** — Pythium damping-off. Apply either broadcast or banded immediately before or after planting in 20-50 gal. of water. Pythium and Phytophthora fruit and root rots. Apply as soil surface spray under vines 4-12 weeks before harvest. Incorporate with irrigation.
(Ridomil 5G)	**Head lettuce** — Pythium damping off. Apply 20-40 lb/treated acre preplant, banded or broadcast with incorporation, or as a surface treatment at time of planting.
(Ridomil/ Bravo 81)	**Broccoli, cabbage, cauliflower** — downy mildew and Alternaria leaf spot, 7 days[a]; **Cucumber, melons, squash** — downy mildew, anthracnose, Cercospora leaf spot, gummy stem blight, leaf blight and scab; **Onions**[c] (dry bulb, seed and green) — downy mildew, Botrytis leaf blight (blast) and purple blotch, dry — 7 days and green — 21 days[a]; **potato** — late blight, tuber and storage rots (Pythium or Phytophthora), early blight and Botrytis vine rot, 7 days[a]; **Tomato** — late blight, early blight, anthracnose, and gray leaf spot.
(Ridomil MZ58)	**Cucumber, melons, squash** — 5 days, no more than 20 lb/A/yr. **Onion** — 7 days, no more than 12.5 lb/A/yr. **Potato** — 7 days, no more than 22.5 lb/A/yr. **Tomato** — 5 days. Use only where downy mildew or late blight problems exist.
(Ridomil PC 11G)	**Beans** (dry and green) — Damping off and seedling rots caused by Pythium and Rhizoctonia. Apply 12 oz. per 1,000 feet of row at planting time.
(Subdue)	*Bedding vegetables* (**broccoli, cabbage, cauliflower, cucumber, lettuce, melon, spinach, squash, tomato**) — Pythium damping-off. Do not use for greenhouse-grown plants.
metiram (Polyram)	**Asparagus** — rust; **potato** — early blight and late blight, 0 days.
oxamyl (Vydate L)	**Carrots, eggplant, pepper, potato, sweet potato, vine crops** — Nematodes. Apply before or at planting. Apply in transplant water for pepper or as foliar spray for peppers and vine crops — 7 days.
PCNB (Terraclor)	**Beans** — base of plants *before* blossoming, soil and seed treatment at planting, or foliar spray. Do *not* feed treated **Bean** vines to livestock. Do *not* apply after first bloom. **Broccoli, Brussels sprout, cabbage, cauliflower** — transplant solution (¾ pint per plant) or row treatment before transplanting. **Pepper, potato, tomato** — soil treatment at or before planting. **Tomato** (greenhouse) — transplant solution (½ pt. of 0.2% per plant). **Garlic** — soil and seed treatment at planting.
streptomycin (Agri-Strep, Agrimycin 17, Streptomycin 17)	**Pepper, tomato** — plant beds only (200 ppm spray); **potato** — seedpiece treatment only (100 ppm dip or dust). Soak cut seed pieces less than 30 min. Do not use treated seed for food or feed.

[a] Number of days between last application and harvest.
[b] There are many other copper materials, but these are most widely available and labeled for use on vegetable crops. Exempt from tolerance if used with good agricultural practices; not exempt if used at the time of harvest or after harvest. See label.
[c] Do not feed treated tops or forage to livestock.
[d] Phytotoxicity to crop or followup crop. See label.

LABEL INFORMATION ON FUNGICIDES AND NEMATICIDES (continued)

Fungicide (tolerance)	Crops and use restrictions
sulfur	Exempt when used with good agricultural practices. See label.
terbufos (Counter 15G)	**Corn** (sweet and pop) — apply in band or furrow at planting.
thiabendazole (Mertect 340F)	**Beans** — white mold, 28 days[a]. **Carrot** — storage rot control. **Sweet potato** — "seed" root treatment. Do not use treated pieces for food or feed. **Potato** — seedpiece treatment and storage rot control.
thiophanate methyl (Topsin-M, Topsin M4.5F)	**Beans** — white mold and gray mold. Snap or dry beans, 14 days; lima, 28 days. **Celery** — early and late blight, 7 days.
(TOPS 2.5D)	**Potato** — seedpiece treatment.
thiram, TMTD	**Onion** — furrow treatment. **Tomato** — 0 days, for leaf spots and fruit rots. Seed treatment: **Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, collard, corn, cucumber, eggplant, endive, kale, kohlrabi, lettuce, lentils, mustard, okra, onion** (bulb, seed, and set), **pea, pepper, pumpkin, radish, spinach, squash, Swiss chard, tomato, turnip, watermelon.** WARNING: Do not use treated seed for food, feed, or oil — 7 days.
triadimefon (Bayleton, 50% WP)	All **Cucurbits** — powdery mildew. May apply a maximum of 1 lb./A/yr.
triphenyltin (Du-Ter, Super-Tin 4L)	**Carrot** — Alternaria leaf spot and late blight — 14 days. **Potato** — early and late blight, 7 days[a]. May be applied through irrigation systems (solid set or center pivot only).
vinclozolin (Ronalin)	**Lettuce** (head or leaf). Sclerotinia drop — 28 days[a]. No more than 3 treatments. **Onion** (dry) — white rot, Botrytis blight, neck rot, 18 days[a].
Zineb	**Tomato** — maximum of 4 lb./A/yr.

[a] Number of days between last application and harvest.
[b] There are many other copper materials, but these are most widely available and labeled for use on vegetable crops. Exempt from tolerance if used with good agricultural practices; not exempt if used at the time of harvest or after harvest. See label.
[c] Do not feed treated tops or forage to livestock.
[d] Phytotoxicity to crop or followup crop. See label.

CONDENSED RECOMMENDATIONS ON DISEASE MANAGEMENT FOR DISEASES OF COMMERCIAL VEGETABLE CROPS FOR 1988

Vegetable	Disease management practices
Asparagus	
Crown or root rots, Seedling blights, and wilt	No resistant varieties are available for control of these diseases. Treating the crowns with mancozeb may aid in control. Phytophthora can be controlled using Ridomil 2E applied over the bed. These diseases are best managed by good asparagus culture. Provide optimal soil fertility, and weed, insect, and rust control. Avoid excessive cutting. Avoid acidic (low pH) and poorly drained soils.
Rust, Cercospora and other leaf and branchlet blights	Grow rust-resistant varieties. Apply maneb, mancozeb, or Polyram to nonharvested fields up to August 15 and to harvested fields after harvest only. Applications should be made at 7- to 10-day intervals. Control is needed in 1- and 2-year beds, even with resistant varieties.
Beans (snap, dry, wax, and lima)	
Most diseases	When possible, use rotations of 2-3 years or longer between bean crops. Strict sanitation.
Seed decay, damping-off, seed-borne stem blights, and root rots	Plant only western-grown, certified seed in a seed bed that is warm (60°-65° F), well-prepared and well-drained. Treat seed with Apron 25WP plus thiram or captan and an insecticide. In-furrow sprays of Ridomil (2E or PC 11G) or seed treatment with Apron 25WP may be helpful for early season root-rot control. PCNB can be used to help control Rhizoctonia.
Root rots	Pythium root rot can be controlled using Ridomil (2E or PC 11G) as a band or furrow treatment at planting. Maintain optimal soil fertility. Utilize rotations of at least 2-3 years with other crops.
Bacterial blights	Plant only western-grown, certified seed. Utilize crop rotations of 2 to 3 years. Avoid cultivating when beans are wet. Field applications of 2-4 pounds of fixed copper (e.g., Kocide 101 or 606) per acre will provide good control of brown spot and halo blight, but only moderate control of common or fuscous blight. Do *not* use copper on fresh market lima beans.
Rust, anthracnose, and other fungal leaf, pod, and stem diseases	Utilize crop rotations of 2-3 years. Apply Bravo at 7- to 10-day intervals starting when disease first appears. Rust-resistant varieties are available for some types of beans. Sulfur can also be used but may be phytotoxic at high temperatures.
Gray mold	Apply Bravo, Benlate, Topsin-M, or Rovral at 25% bloom and repeat at full bloom. Thorough coverage of blossoms is essential.
White mold	Apply Botran (snap beans only), Benlate, Roveral, or Topsin-M at 25% bloom, and repeat at full bloom.
Mosaic virus diseases	Plant varieties with resistance to bean common mosaic, NY15 strain of common mosaic, and bean yellow mosaic. Avoid planting near clovers, birdsfoot trefoil, gladiolus, etc.
Soybean cyst nematode	Rotate at least 2-3 years with corn, small grains, alfalfa, or other nonhost crop. Do *not* include soybeans in the rotation. Temik may be used on dry beans.
Root-knot and lesion nematodes	Apply Temik (dry beans only) or Mocap (snap or lima beans) at planting.
Beet (garden), Swiss chard	
Seed rot, damping-off, and seed-borne leaf spot	Sow in a well-prepared seed bed. Treat seed with captan, thiram, or Apron (for Pythium). Make sure boron levels are adequate. Several soluble-boron formulations are available.
Cercospora leaf spot	Apply fixed copper weekly at the first sign of disease. Separate new from old plantings.

CONDENSED RECOMMENDATIONS ON DISEASE MANAGEMENT (continued)

Vegetable	Disease management practices
Crucifer crops (broccoli, Brussels sprout, cauliflower, cabbage, Chinese cabbage, collard, kale, kohlrabi, mustard, radish, rutabaga)	
Seed rot, damping-off, black rot, blackleg, Alternaria leaf spot	Sow only western-grown, hot-water-treated seed. Seed also should be treated with thiram or captan. Place seed beds where no crucifer has grown for 4 years or more and where water will not drain from fields recently planted to crucifers. Ridomil 2E applied at planting time will control Pythium damping-off and Phytophthora basal stem rot.
Wirestem (*Rhizoctonia*)	Incorporate PCNB-captan in upper 3 inches of soil before planting or drench after planting.
Clubroot	Use only healthy transplants. Avoid soils with a history of clubroot. If clubroot is present, adjust soil pH to 7.2 with hydrated lime. Rotate out of cruciferous crops for 7 years. Apply PCNB (Terraclor 75WP) in transplant water; use ¾ pint per plant.
Black rot and blackleg	Use a crop rotation of 4 years or more. Use only hot-water-treated seed. Use care in the selection of plant bed sites. Be sure no drainage occurs to seed bed from old plantings. Control wild mustard and other cruciferous weeds. Purchase only certified, disease-free transplants. Do not dip transplants before planting. Sprays of fixed copper may help control black rot. Rovral can be used to control blackleg on broccoli. Bravo applied to control downy mildew may also help control blackleg. Some cabbage varieties resistant to black rot are available. Losses are generally lower where direct seeding is used.
Downy mildew, Alternaria leaf spot, and other fungal leaf diseases	Apply Bravo or Ridomil/Bravo 81W at weekly intervals. Start applications in seedbed or when plants are young. Rotate with noncruciferous crops and use disease-free seed or transplants. Ridomil can be used to control downy mildew on some cruciferous crops.
Internal tipburn	Plant resistant varieties. Avoid overfertilizing, especially with nitrogen.
Fusarium yellows	Plant only yellows-resistant varieties.
Radish black root	Plant resistant varieties. Avoid planting radishes in severely infested soil.
Nematodes	Mocap (cabbage only) or Nemacur (Brussels sprout and cabbage only) may be applied at planting.
Carrots, Parsnips	
Seed rot, damping-off	Treat seed with captan or thiram. Plant in well-drained seed bed. Avoid overwatering.
Cercospora leaf spot, Alternaria leaf blight	Apply Rovral, Du-Ter, or Bravo on 7-10 day intervals. Start when disease first threatens and repeat as needed.
White mold	Apply Benlate at 7- to 10-day intervals. Use a crop rotation of 3-4 years.
Aster yellows	Use insecticides to control leafhoppers that transmit the mycoplasma. Excellent early season leafhopper control is essential. Control must occur *before* leafhoppers feed.
Root-knot nematode	Fumigate mineral soils with Telone II, Vapam, or Vorlex, *or* practice a 3-year rotation with corn or other nonhost crops. Control broadleaf weed hosts. Vydate L may be applied at planting (carrot only).
Parsnip canker, leaf spot, mildew	Spray with fixed copper 3 times at 10-day intervals at first sign of disease. Ridge soil over the shoulders to prevent canker infections.
Celery, Parsley	
Seed rot, damping-off, and seed-borne leaf blights	Treat seed with hot water, then captan or thiram. If damping-off starts, spray 2-3 times, 5-7 days apart with Bravo or fixed copper. Seed 2-3 years old is free of late blight.
Leaf blights and spots (celery only)	Spray maneb, Benlate, Topsin-M, Dyrene, or Bravo at 7-10 day intervals.
Aster yellows and Root-knot nematode	(See the section on Carrots and Parsnips)
Corn (sweet and pop)	
Seed rot, seedling blights, and seed-borne diseases	Plant seed treated with captan or thiram plus an insecticide. Plant shallow in warm, well-drained soil.
Goss' bacterial wilt	Use 2- to 3-year crop rotations when using susceptible corn (dent or sweet) varieties.
Stewart's disease	Control corn flea beetles on young plants with an insecticide, or plant tolerant varieties.
Smut	Plant tolerant varieties. Control corn borers as first tassels appear.
Maize dwarf mosaic, chlorotic dwarf, and wheat streak mosaic	Control johnsongrass and volunteer wheat. Plant wheat after the fly-free date. Some varieties tolerate maize dwarf better than others, but none are highly resistant.
"Helminthosporium" leaf blights, and anthracnose leaf blight	Spray mancozeb, maneb, or Bravo when disease first appears. Crop rotation and clean tillage will help reduce disease risk.
Rusts	Spray as for "Helminthosporium" blights or plant resistant varieties.
Nematodes	Apply Furadan, Counter, or Mocap (sweet corn only) at planting time.
Cucurbits (cucumber, muskmelon or cantaloupe, pumpkin, squash, and watermelon)	
General	Use a crop rotation of 3-4 years. Grow resistant varieties whenever possible.
Seed rot, damping-off, seed-borne diseases	Plant only certified, western-grown seed treated with captan or thiram. Damping-off can be treated with a captan or Ridomil 2E seed-bed drench. Plant shallow in warm soil.
Bacterial wilt	Provide season-long control of striped and spotted cucumber beetles. Start as the plants begin to emerge. Planting-time treatment with Furadan will provide moderate control for 3-4 weeks. Supplemental insecticide use will be necessary.

CONDENSED RECOMMENDATIONS ON DISEASE MANAGEMENT (continued)

Vegetable	Disease management practices
Cucurbits (cont.)	
Anthracnose, scab, blossom blights, and gummy stem blight, or black rot	Grow resistant varieties when possible. Spray weekly with Bravo, Benlate, or Ridomil/Bravo 81W. Start when vines begin to run. Store only blemish-free fruit.
Downy mildew, Alternaria leaf blight	Grow resistant varieties when possible. Maintain ample but *not* excessive nitrogen fertility. Apply Bravo on a weekly schedule. Ridomil/Bravo 81W provides excellent control of downy mildew. Practice a 2-3 year rotation.
Fruit spots and rots	Maintain fungicide schedule as for anthracnose throughout the season. Avoid harvest injuries.
Fusarium wilt	Grow only resistant varieties.
Angular leaf spot	Apply fixed copper sprays in combination with Bravo. Start applications early in the season. Practice crop rotations of 3-4 years. Resistant cucumber varieties are available.
Powdery mildew	Apply Bayleton or Karathane WD at the first sign of disease and again 10 days later for Karathane (10-14 days later for Bayleton). Where Benlate or Bravo is applied to control other diseases, mildew will be controlled under moderate disease pressure. Plant resistant varieties where possible. Karathane can cause injury at high temperatures.
Mosaic viruses	Control aphids and beetles in the field. Eliminate broadleaf weeds around field borders before plant establishment. Plant only mosaic-resistant cucumbers.
Root-knot nematode	Fumigate with Vapam, Telone C-17, Telone II, or Vorlex in the fall before planting or use Furadan or Vydate L at planting.
Eggplant	
Seed rot, damping-off, and seed-borne diseases	Plant hot-water-treated seed when possible. Treat the seed with captan or thiram. Ridomil can be used for Pythium damping-off.
Phomopsis blight, Alternaria leaf spot, Cercospora leaf spot, and anthracnose	Follow good sanitary practices. Use a crop rotation of 2-3 years. Avoid bruising fruit; handle carefully at all times. Weekly sprays with copper fungicides may aid in control.
Verticillium wilt, nematodes	Fumigate the soil with Vapam, Vorlex, or methyl bromide plus chloropicrin. Planting under a black plastic mulch will help reduce disease severity. Vydate L will control nematodes.
Horseradish	
Leaf spots, white rust	Apply fixed-copper fungicides. Start when conditions are wet or dews are heavy. Continue until a killing frost occurs. Practice a 2-year field rotation with any other crop.
Brittleroot	Plant clean sets. Control leafhoppers that spread the disease agent.
Verticillium wilt, nematodes	Fumigate the soil before planting with Telone C-17.
Lettuce, Endive, Escarole	
Seed rot, damping-off, Gray mold	Treat seed with captan or thiram. In the field or seed bed, work Botran into the soil before planting and spray Botran 7 days after transplanting. Repeat when plants are 50% mature. Ridomil 5G or 2E as a soil application at seeding controls Pythium damping off.
Aster yellows, mosaic viruses	Control leafhoppers and aphids throughout the season. Early season control is most important.
Rhizoctonia bottom rot, Sclerotinia drop, gray mold	Plant on raised beds and deep plow when possible. Apply Rovral or Ronalin at 3-leaf stage and again 10 and 20 days later. Botran applications as previously described may help. Use 100 gallons of water carrier per acre.
Gray mold	Apply Botran (leaf type only) at 7- to 10-day intervals.
Nematodes	Apply Telone C-17, Telone II, Vapam, or Vorlex in the field in the fall before planting. In greenhouses, steaming the soil will provide control.
Okra	
Seed rot, damping-off	Treat seed with captan or thiram plus Apron 25WP. Plant in warm, well-drained soil.
Fusarium and Verticillium wilts	Fumigate soil with Vorlex, Vapam, or methyl bromide plus chloropicrin.
Onions, garlic, leek, chives, shallot	
Smut, seed rot, damping-off	Treat the seed with captan or thiram. Use Methocel sticker to pellet the seed with fungicide. Use 1⅓ pounds of active ingredient to 20 pounds of seed for set onions; 6 pounds of active ingredient to 8 pounds of seed for bulb onions. Mancozeb or Ridomil can be used as an in-furrow drench at planting.
Blast, downy mildew, Alternaria purple blotch, Botrytis neck rot	Apply Dyrene, Rovral, Ronalin, or Bravo on a weekly schedule. Begin spraying with first ozone alert. Continue until harvest. Bravo has given superior control. Use Ridomil MZ58 or Ridomil/Bravo 81W when downy mildew appears.
Bulb and stem nematode, root-knot nematode	Fumigate with Telone II, Telone C-15, D-D, Vapam, or Vorlex. Eradicate volunteer plants from fields with a history of bulb and stem nematode.
White rot of garlic	Apply Rovral on cloves and in furrow covering soil. Plant disease-free cloves in well-drained soil.
Fusarium basal rot	Avoid heavily infested fields. Grow resistant varieties. Cure bulbs rapidly and properly.
Storage decays	Maintain excellent control of leaf diseases in the field. Maintain dry storage conditions.
Yellow dwarf	Control aphids. Keep old and new plantings as far apart as possible. Destroy volunteer onions.
Peas	
Seed rot, seedling and seed-borne diseases	Plant western-grown seed treated with captan or thiram and Apron 25WP plus an insecticide. Graphite at 1 ounce per bushel may be added to reduce friction in the drill.

CONDENSED RECOMMENDATIONS ON DISEASE MANAGEMENT (continued)

Vegetable	Disease management practices
Peas (cont.)	
Root rots	Index production fields. Avoid planting in fields with an index of 75 or higher. In fields with a lower root rot index, apply dinoseb (Premerge 3) or trifluralin preplant incorporated. Ridomil 2E in the seed furrow gives good Pythium damping-off and root rot control.
Fusarium wilt and near wilt, virus diseases	Grow resistant varieties. Viruses are spread by aphids. Plant as early as possible in well-fertilized and well-drained soil. Rotate 4 years or more.
Powdery mildew	Apply sulfur dust or spray when mildew first appears and temperatures are less than 80°F. Two applications a week apart provide good control. Plant resistant varieties.
Peppers	
Seed rot, damping-off, and seed-borne diseases	Use only western-grown seed and treat with hot water or a household bleach (Clorox) soak. The bleach soak controls seed-borne bacterial spot. Use 1 part bleach to 3 parts water, soak 1 minute. Use 1 gallon of fresh bleach-water solution to 1 pound of seed. Rinse thoroughly before treating with captan or thiram seed protectant. Ridomil can be used to control Pythium damping-off.
Bacterial spot	Use crop rotations of 2-3 years, excluding small grains and tomatoes. Control broadleaf weeds in and around field borders. Apply fixed copper plus streptomycin (200 ppm) to seedlings. After transplanting, apply fixed copper plus maneb on a 5- to 7-day interval. Purchase only certified, disease-free transplants. Planting peppers in narrow strips between early planted corn may help reduce spread during severe rain and wind storms. Maintain a high balanced level of soil fertility.
Phytophthora crown rot	Plant on raised beds in well-drained soil. Treat soil with Ridomil 2E. Rotate to non-solanacious crops for 3-4 years.
Anthracnose, Cercospora leaf spot, other fungal leaf spots, and fruit rots	Use disease-free seed. Practice 3-year crop rotation. Burn or plow down crop refuse after harvest.
Nematodes	Add Vydate L to transplant water and supplement with foliar applications. Follow label directions.
Verticillium wilt	Fumigate soil with Vapam, Vorlex, or methyl bromide plus chloropicrin.
Virus diseases	Grow resistant varieties. Control aphids that transmit viruses. Eliminate broadleaf weeds within 150 ft. of fields before crop is established. Plant only healthy transplants.
Potatoes (Irish)	
General	Purchase only certified seed. Seed-production fields should be inspected for virus, nematode, or fungal disease problems. Good sanitation and seed-handling practices will reduce losses.
Seedpiece decay, seed-borne diseases, Verticillium wilt, and blackleg	Treat seed with captan, maneb, mancozeb, or TOPS 2.5D. Keep seed storage at approximately 40°F during the winter. In the spring, warm the seed to 65°-70°F for 2-3 weeks before cutting. Streptomycin may be added to fungicide dusts to improve the control of bacterial diseases. Avoid bruising seed during handling.
Scab	Plant resistant varieties. Do *not* apply manure or other organic matter immediately before the potato crop. Maintain acidic soil.
Storage rots	Store healthy, sound, unbruised mature potatoes. Maintain a proper storage environment. Apply Mertect 340-F as a spray to unwashed tubers before storage. It helps control Fusarium dry rot.
Rhizoctonia	Use a Terraclor 2 EC soil treatment. Practice a 3-year rotation. Plant shallow.
Verticillium wilt	Practice crop rotation, use only seed free of Verticillium. Control root-knot and root-lesion nematodes. Soil fumigation with Vapam or Vorlex may be practical.
Nematodes	Where soil samples indicate damaging levels of nematodes, apply Temik or Vydate L, or fumigate with Vapam, Vorlex, D-D, or Telone C-17.
Early blight and late blight, leak, pink rot	Apply maneb, mancozeb, Bravo, Polyram, Du-Ter, Super-Tin, or Dyrene on 7- to 10-day schedule. Maintain an adequate supply of nitrogen throughout the season to provide good control of early blight. Use Ridomil MZ58, or Ridomil/Bravo 81W only where late blight, leak, and pink rot are a threat. Avoid bruising tubers, especially in hot weather.
Virus diseases and purple-top wilt (Aster yellows)	Plant only certified seed. Control aphids and leafhoppers with insecticides. Practice clean cultivation. Rogue first infected plants including tubers.
Rhubarb (greenhouse only)	
Botrytis leaf rot	Apply Botran (3 days to harvest) or fixed copper after budding and at weekly intervals.
Crown and root rots	Plant only in well-drained soil. Maintain optimal soil fertility. Drench the crowns with fixed copper at 3 pounds per acre in the early spring and after harvest if crown rot is a problem.
Spinach	
Seed rot and damping-off	Treat seed with captan or thiram. Apply Ridomil 2E for Pythium damping-off.
Downy mildew or blue mold, white rust, anthracnose, and other fungal leaf diseases	Grow downy mildew-resistant varieties. A soil application of Ridomil 2E (2-4 pts./treated acre) at planting in 50 gal. water controls blue mold and white rust for about 60 days.
Cucumber mosaic virus or blight	Grow tolerant varieties. Control aphids that spread the virus.
Sweet potatoes	
Black rot, foot rot, Fusarium wilt and scurf	Grow resistant varieties. Use clean soil in plant beds and maintain temperature of 80° to 85°F. Plant disease-free roots and use crop rotations of 3-4 years. Dip the roots or sprouts in Botran or Mertect 340-F.
Storage rots	Fumigate storage crates and houses with formaldehyde. Use Botran as a postharvest dip. Cure and store only healthy, blemish-free roots.
Nematodes	Plant resistant varieties. Practice crop rotation. Temik, Mocap, Vydate L, or Dasanit (suppression only) may be used for chemical control; or fall fumigate with Vapam or Vorlex.

CONDENSED RECOMMENDATIONS ON DISEASE MANAGEMENT (continued)

Vegetable	Disease management practices
Tomatoes (field)	
Seed decay, damping-off, and seed-borne diseases	Plant hot-water- or household bleach-soaked seed that has been treated with captan or thiram. See treatment for pepper seed. Use Ridomil 2E drench for Pythium damping-off in the seed bed.
Bacterial spot, speck, and canker	Purchase only certified, disease-free plants. Use crop rotations of 3-4 years, excluding small grains. In the seed bed, spray with fixed copper plus streptomycin. After transplanting, spray with fixed copper plus mancozeb or Bravo C/M. Once established, bacterial spot and canker are difficult to control.
Septoria blight, early blight, anthracnose, buckeye rot, gray leaf spot, and leaf mold, gray mold, and white mold (*Sclerotinia*)	Apply maneb, mancozeb, Dyrene, or Bravo on a 7- to 10-day schedule after the first sign of disease or after the first fruits form. A soil surface spray of maneb after the last cultivation will improve anthracnose control. Benlate may be used for Botrytis, Septoria, white mold, and leaf mold control. Ridomil 2E or Ridomil/Bravo 81W helps control buckeye, Pythium fruit rots, and late blight.
Blossom-end rot	Mulch plants or maintain uniform soil moisture. Four weekly applications of calcium nitrate starting when the fruits are grape size may reduce losses. Avoid cultivation close to plants.
Verticillium wilt and Fusarium wilt	Grow only resistant (VF) varieties. Avoid soils with a history of wilt.
Viruses	Take care to avoid infecting the seedlings. Start with virus-free seed. Control insects and broad leaf weeds in and around fields. See greenhouse tomatoes below.
Nematodes	Plant root-knot-resistant varieties. Vydate L or Dasanit may be applied at planting. Fall fumigation with Vapam or Vorlex may also be used.
Tomatoes (greenhouse)	
Virus diseases	Start with hot-water-treated seed. Do not allow the use of tobacco on the premises. Smokers should wash their hands with soap and hot water before working with plants. If possible, plant TMV-resistant hybrids. Control insects. Remove first infected plants if possible.
Botrytis gray mold, leaf mold, gray leaf spot, and early blight	Avoid excessive humidity by heating and venting, especially at night during the fall, early winter, and early spring. Spray weekly with Benlate, mancozeb, or Bravo *or* fumigate with Exotherm Termil. Botran as a directed spray controls stem canker; cover stems up to 18-24 inches from ground.
Nematodes, root rots, and soil-borne TMV	Steam the plant beds. Plant resistant varieties whenever available.

GENERAL SUGGESTIONS ON FUNGICIDE APPLICATION

1. Cover the foliage uniformly. *Ground equipment* — Apply 75 to 125 gallons per acre at approximately 400 pounds per square inch of pressure. Lowering volumes and/or pressures may provide adequate coverage, but high-volume, high-pressure applications provide ideal coverage. Make sure the sprayer is functioning properly. Check the nozzles for cleanliness and wear. Boom, height, accuracy of pressure gauge, agitation, and calibration should also be checked. *Aerial application* — Apply recommended amounts of pesticide per acre in 3 to 5 gallons of water. Make sure nozzles are properly aligned and clean, so uniform application is achieved. Cover a swath no wider than is reasonable for the aircraft and boom being used. Spray only those fields that are suitable for aerial application. Avoid fields of irregular shape or topography, particularly if they are bounded by power lines, trees, or other obstructions.
2. Whenever possible spray when the air is still or when wind velocity is not excessive (less than 10 mph).
3. Avoid situations where pesticide drift may cause needless problems.
4. When it is compatible with the product label, use a spray adjuvant (surfactant). Some commonly available surfactants are: Kalo: Bio 88, Bio-Film, and Regulaid (for systemic fungicides); Hopkins: Plyac; Rohm & Haas: Triton AG-98, B-1956, CS-7; Ortho: Chevron Spray Sticker, Chevron Spreader, X-77 Spreader; Miller: NuFilm P, NuFilm 17; DuPont: Spreader Sticker. Spray adjuvants are most useful on cabbage, cauliflower, Brussels sprout, onions, and peppers.

GENERAL SUGGESTIONS ON SOIL FUMIGATION

Follow the manufacturer's directions exactly. Fumigants work best in light, loose soils that are free of trash, clods, and lumps. Avoid recontaminating treated soil. It is best to apply fumigants during the fall before planting. In general, the soil temperature must be at least 55° to 60°F at the 6-inch depth, with a time lapse of 21-28 days between treating and seeding. Some require gas-tight plastic covers. Many fumigants are restricted-use chemicals.

GENERAL SUGGESTIONS FOR USE OF NEMATICIDES

Use nematicides only where soil analysis shows a nematode problem to be present. Follow soil sampling instructions in *Report on Plant Diseases* No. 1100, "Collecting and Submitting Soil Samples for Nematode Analysis." This publication is available for 50 cents from Extension Plant Pathology, N-533 Turner Hall, 1102 South Goodwin Ave., Urbana, IL 61801. Checks should be made out to the University of Illinois.

1990 Plant Disease Control Guide: WOODY ORNAMENTALS

Disease control programs for woody ornamental trees and shrubs should be based on a thorough knowledge of the diseases that are likely to appear and the plants that are susceptible to attack and on an early and accurate diagnosis of the problem. Control measures *must* start before or at the early onset of disease, but preferably before symptoms appear. Disease control programs should begin with the purchase of the best seed or planting materials available and continue until the plants are sold or discarded.

Traditionally, four fundamental principles apply to plant disease control. The four may be applied individually or concurrently for integrated control of infectious agents or pathogens. These principles are exclusion, eradication, immunization, and protection. All cultural and chemical practices that are used to keep plants from becoming diseased can be placed into one of these four categories.

Exclusion involves preventing the disease-causing organisms and agents from becoming established in or around susceptible plants. Exclusion is achieved through federal or state embargoes, quarantines, inspections, and disinfection of seeds, plants, cuttings, or other propagative plant parts. Other methods include certification of plants and cuttings before shipment and culture indexing of planting stock to ensure freedom from pathogens.

Eradication is the elimination of the disease-causing agent or pathogen after it has become established in or on a plant where it is growing or being stored. Eradication involves the removal and destruction of infected plant parts, diseased plants, infected debris, weeds, alternate hosts, and other overwintering host plants. It also involves seed or plant treatment with wet or dry heat or a systemic chemical such as a multipurpose soil fumigant; crop rotation; and cleaning and disinfesting potting benches, soil bins, greenhouse benches, nursery beds, storage areas, tools, and equipment.

Immunization involves growing resistant or immune species, varieties, or cultivars and treating the disease with a systemic chemical that internally kills, inactivates, or protects against infection. Unfortunately, there are no woody ornamental plants resistant or immune to all diseases. Much less time and effort has been put into developing disease-resistant trees and shrubs than into field crops, vegetables, and fruits.

Protection is the placing of a physical or chemical barrier between the susceptible part of the host plant and the disease agent or pathogen. Protection usually means uniform applications of recommended disease-control chemicals, including fungicides, bactericides, or nematicides, as dusts, sprays, or soil drenches. Chemicals should be applied to the plant or its propagative parts *before* the pathogen arrives.

Protective cultural practices include proper spacing of plants; time and depth of planting; proper soil reaction (pH); careful handling of plants and propagative parts during harvest, grading, and packing; proper lighting, temperature control, watering, fertilization, and pruning; and the alteration of the air and soil environment to make it unfavorable for the pathogen to infect, develop, reproduce, or spread during growth, storage, and shipment.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
COOPERATIVE EXTENSION SERVICE
CIRCULAR 1260-90 (revised annually)

COLLEGE OF AGRICULTURE
November 1989

To be successful, the right chemical must be applied at the right concentration, at the right time, and in the right way. Correctly applying the proper chemicals ensures an active and complete chemical barrier on the susceptible plant surface during the time when infection may occur. Several applications, spaced about 7 to 10 days apart for protective fungicides and 10 to 21 days or longer for systemic fungicides, are usually needed to keep expanding foliage, flowers, and fruits covered with a protective film.

Protection also includes the killing of insects, mites, and other inoculating agents before these pests can feed and infect plants with pathogens carried on or in their bodies. Some seed treatments, such as captan, thiram, and Apron, will protect against seed- and soilborne organisms.

To help in diagnosing the common diseases of woody ornamentals, an identification key is presented in Table 1. The symptoms in the key are divided into those that appear on the leaves; twigs, branches, and trunk; and on the roots.

The pesticides listed in Table 2 are presented by their common and trade names as much as possible. The percentage of active ingredients and formulation information are presented adjacent to these names. Various formulations of common fungicides such as Truban are available: wettable powders (WP), emulsifiable concentrates (EC), and granules (G). The fact that Truban 25% EC is cleared for use on Chamaedora palm, for example, does not mean that the 30% WP or the 5% G formulations are also legal to use on this species. Specific formulations differ in their percentages of active ingredient and therefore in efficacy and crop safety.

Some common fungicides such as zinc ion and maneb complex (mancozeb) are often available under several major trade names. For example, the labels of DuPont's Manzate 200 and Rohm & Haas's Dithane M-45 list the same percentages of active ingredient, yet Manzate 200 is legal to use on a number of ornamentals while Dithane M-45 is not. Rohm & Haas's Fore is the equivalent of Dithane M-45 for use on ornamentals. Always read and follow label directions and precautions. Use the product only on the plants listed on the label. It is illegal to do otherwise.

This publication presents the disease control application intervals and rates for various crops as approved by the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA) as of September 1, 1989, to the best of our knowledge.

Label registrations can change at any time, Thus, the recommendations in this circular may become invalid. The user is encouraged to carefully read and follow the most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Watering

During the growing season, woody ornamentals should receive the equivalent of one inch of water each week as rainfall or supplemental irrigation. If irrigating, apply water in the morning on a rising temperature, *not* during late afternoon or evening. Where possible, use a soaker hose or feeding needle rather than overhead watering. Try to keep water off the foliage.

NOTE: The information in the following tables is for educational purposes only. Reference to commercial products or trade names does not constitute an endorsement by the University of Illinois and does not imply discrimination against other similar products. Trade names are presented for reasons of clarity only. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

Table 1. Disease Symptoms of Woody Ornamentals

General symptoms	Specific symptoms	Disease
LEAVES Small to large scattered spots in various sizes, shapes, and colors.	Roundish spots; may contain dark, speck-sized fungus fruiting bodies.	Fungus leaf spot
	Spots may have dark margins or drop out (shot-hole).	Spot anthracnose Scab Shot-hole
	Black, shiny spots.	Tar spot
	Irregular dead areas in leaves.	Leaf blight or blotch
	Variously colored "blisters"; leaves often partly or entirely puffy, thickened, or curled.	Leaf curl or blister
Leaves spotted or blighted; later covered with dusty mold growth.	Tan to gray, coarse mold.	Botrytis blight or gray-mold
	White to light gray mold, powdery to mealy.	Powdery mildew
	Black mold, sooty or crusty.	Sooty mold
	Yellow, orange, reddish-orange, reddish-brown, chocolate brown, or black mold in raised pustules.	Rust
Leaves mottled light and dark green or yellow.	Irregular mosaic pattern	Mosaic
	Yellow-green or reddish-brown rings, "oakleaf," "watermark," or line patterns.	Ringspot
Leaves wilt, wither, and die; may involve one or many branches or entire plant.	Discoloration in outer sapwood.	Wilt disease
	Foliage appears scorched by fire; twig tips curl downward to form "shepherd's crooks."	Fire blight

General symptoms	Specific symptoms	Disease
LEAVES, cont.	Other possible causes include: wood rot; black knot; drought or excess water; transplant shock; construction damage; change in soil grade; girdling roots; injury from insects, rodents, or other animals; pesticide or fertilizer damage; winter and frost injury; salt damage; lightning or fire injury; roots in septic tanks or sewer lines; or other mechanical injuries.	Miscellaneous diseases and injuries
Leaves "scorched" at margins and tips; often later between the veins.		Leaf scorch (See also Miscellaneous diseases and injuries above)
TWIGS, BRANCHES, AND TRUNKS Twigs and branches die back, usually starting at the tips; foliage commonly wilts, withers, and dies.	Discoloration in outer sapwood.	Wilt disease
	No discoloration in outer sapwood. (See Root Symptoms below.)	Root rot
	Foliage appears scorched by fire; twig tips curve downward.	Fire blight
	Sap flows down trunk and branches from wounds; becomes gray to white stain on bark.	Wetwood
	Definitely marked, often sunken, swollen, flattened, or targetlike areas (cankers) in bark and outer wood of twigs and branches.	Canker or dieback
	Wood in branches or trunk decays; bracket, shelf, or mushroom fungi may form on bark surface or trunk base.	Wood rot

General symptoms	Specific symptoms	Disease
TWIGS, BRANCHES, AND TRUNKS, cont.	Other possible causes include: injury from fertilizer, pesticide, or salt; drought or excess water; lightning or fire injury; transplant shock; winter injury; excess shade; construction damage; girdling roots; insect, rodent, or other animal injury; various types of mechanical damage; change in the soil grade; or chlorosis.	Miscellaneous diseases and injuries
Greatly swollen areas on twigs, branches, or trunk.	Galls on *Prunus* rough and black or olive green and velvety in spring.	Black knot
	Roundish or spindle-shaped galls on branches or trunk; often covered with yellowish to orange dusty masses in spring or early summer.	Rust gall
	Rough, roundish, tumorlike galls, usually at or near soil line or graft union.	Crown gall
	Large, irregular swellings anywhere on trunk or scaffold limbs of older trees.	Burr
Dense, brushy masses of stubby shoots form on branches.		Witches'-broom
ROOTS Trees lose vigor, growth slows, foliage off-color; tops (crowns) may wilt and die back.	Roundish, rough, tumorlike galls on roots, up to a foot or more in diameter.	Crown gall
	Roots decay; feeder roots die back; mold growth under bark or over roots; usually shoestringlike black strands are evident.	Root rot

General symptoms	Specific symptoms	Disease
ROOTS, cont.	Roots somewhat necrotic, lacking feeder roots; appear stunted or have small galls.	Nematodes (must be confirmed by soil or root analysis)
	Other possible causes include: excess water, change in soil grade, construction damage, injury from fertilizer or pesticide, girdling roots, winter injury, salt, insect or animal feeding, or wilt disease.	Miscellaneous diseases and injuries

Fertilization

Unthrifty and undernourished woody ornamentals are susceptible to a variety of diseases and environmental stresses. Their vigor can often be greatly improved by periodic applications of fertilizer and timely watering. Soil tests are always suggested prior to feeding, especially if a soil or lawn fertilization program has been in effect. In general, a 10-10-10 (NPK) fertilizer is recommended at the rate of 2 to 4 pounds per inch of trunk diameter at breast height. The fertilizer can be injected into holes in the ground evenly distributed beneath the tree and extending out to the drip line or beyond. Alternatively, apply fertilizer by surface broadcasting about 1 or 2 pounds of actual nitrogen per 1,000 square feet during the dormant season; ammonium nitrate or nitrate of soda are acceptable compounds.

Sanitation

Proper selection of planting site, planting method, and materials, as well as soil preparation, pruning, winter protection, disease and pest control, and avoidance of unnecessary wounding will aid in control of a wide range of diseases.

Prune during dry weather and sterilize tools frequently between cuts. Use a fresh 10 percent solution of liquid household bleach, 70 percent denatured alcohol, or radiator antifreeze-type alcohol or 4 percent formaldehyde. When pruning or removing diseased wood, paint the newly exposed inner bark and sapwood with a germicidal or fungicidal coating. Shellac is useful for many diseases. Follow the shellac with a tree wound paint containing benomyl (Benlate) fungicide, 50% WP, at the rate of 1 gram in 5,000 grams or 2-2/3 ounces per 100 gallons. This mixture, although harmless to living bark, is toxic to spores of such canker- and wilt-producing fungi as *Botryosphaeria*, *Ceratocystis*, *Cytospora* (*Valsa*), and *Verticillium*.

Surfactants

Wetting, spreading, and sticking agents (surfactants) are often added to spray mixtures for hard-to-wet foliage such as on conifers, broadleaf evergreens, boxwood, and roses. Some commercial spreader-stickers available for tank mixing include Biofilm Spreader-Sticker, Chevron Spray Sticker, Citowett Plus, Filmfast Spreader-Sticker, Miller Nu-Film -P and -17, De-Pester Spreader-Activator, DuPont Spreader-Sticker, and Aqua T Non-ionic Organic Wetting Agent. Commercial spreaders include Chevron Spreader, Chipco and Rhodia Spreader-Activator, Flo-Wet, Multi-Film L and X-77, Ortho X-77 Spreader, Pinolene, Sure Spred, Surfactant II, Triton B-1956, Tween 20, Flexit, Sanomerse 80, and Penex. The fungicide label usually indicates any restrictions that should be observed in selecting compatible surfactants. Use these commercial preparations according to label directions. The addition of any extra wetting, spreading, or sticking agent may cause excess runoff and result in a poor spray deposit.

Leaf Scorch of Broadleaf Evergreens

Winter drying or leaf scorch of broadleaf evergreens, including magnolia, holly, rhododendron, and boxwood, can often be prevented by applying an antidesiccant such as Folicote, Foli Guard, Vapor-Gard, or Wilt Pruf NCF, according to label directions. Apply to the upper surfaces of leaves in late November or early December and repeat again in midwinter.

Fungicide Sprays

In general, spray only when a destructive disease is a known threat. Annual sprays or routine spray schedules are required for relatively few diseases in home, recreational, or industrial plantings. Most fungicide sprays are designed to protect against infection. To be effective, the fungicide must be on the plant before infection occurs. Rainy, foggy, or very humid weather favors infection by practically all fungi and bacteria. When possible, therefore, spray schedules should be altered to provide maximum fungicidal protection during rainy periods.

Table 2. Suggestions for Specific Trees and Shrubs

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
ALDER			
Powdery mildew	benomyl, 50% WP[2] sulfur, 80-95% WP Rubigan A.S., 11% L	1/2 2-3 See label	Spray 2 or more times, 7 to 10 days apart starting when disease first appears.
ALMOND—See Cherry.			
AMELANCHIER, SHADBUSH, SERVICEBERRY, JUNEBERRY			
Cedar rusts	thiram, 65-75% WP mancozeb, 80% WP	1-1/2 to 2 1-1/2 to 2	Spray 3 times at 10-day intervals starting when new growth appears in the spring.
Powdery mildew	Karathane, 19.5% WP benomyl, 50% WP sulfur, 80-95% WP Bayleton, 25% WP	1/2 1/2 2-3 2-4 oz[b]	Spray when disease first appears or as leaves start to expand. Repeat 2 or 3 times 10 days apart.
APPLE—See Crabapple.			
ARBORVITAE			
Phomopsis needle and twig blight	benomyl, 50% WP mancozeb, 80% WP	1 1-1/2 to 2	Only new growth is susceptible. Spray whenever new growth appears and after shearing or wet weather. Spray at bud-break and repeat at 10- to 14-day intervals until new growth has matured.
Root rot	Banrot	See label	Apply 40% WP product in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Re-treat at 4- to 12-week intervals. Work 8% granular product into soil before planting.
Nematodes	Vydate 2L[7]	See label	See Boxwood.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
ASH			
Anthracnose Fungus leaf spots	copper[3] maneb, 80% WP benomyl, 50% WP[2] mancozeb chlorothalonil Duosan, 75% WP Zyban, 75% WP	See label 1-1/2 to 2 1 See label See label 1-1/2 1-1/2	Apply when buds begin to open. Repeat 10 to 14 days later. Maneb and mancozeb also control rust.
AZALEA—See Rhododendron.			
BARBERRY			
Bacterial leaf spot and twig blight Fungus leaf spot Blotch Anthracnose	copper[3]	See label	Spray 2 to 3 times, 10 days apart, beginning when new leaves appear in spring.
Nematodes	Dasanit, 15G[7] Vydate 2L[7]	See label See label	See Boxwood. See Boxwood.
BASSWOOD—See Linden.			
BEECH			
Fungus leaf spot	copper[3]	See label	If severe, spray twice, 10 days apart, starting as the leaves begin to unfold.
Powdery mildew	Karathane, 19.5% WP benomyl, 50% WP sulfur, 80-95% WP Rubigan A.S., 11% L	1/2 1/2 2-3 See label	If severe, spray twice, 10 days apart, starting when mildew is first seen.
BIRCH			
Leaf blister	copper[3] liquid lime-sulfur	See label 2 gal[b]	Spray once before buds swell in early spring.
Anthracnose	benomyl, 50% WP mancozeb, 80% WP	1 1-1/2	Spray twice, 10 to 14 days apart, starting at budbreak.
Rust	mancozeb, 80% WP Bayleton, 25% WP	1-1/2 2-4 oz[b]	Spray several times 10 days apart. Start about a week before rust normally appears.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
BITTERSWEET			
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 1/2 See label	If severe, spray 2 or 3 times at 10-day intervals starting when mildew first appears.
Fungus leaf spots	copper[3]	See label	Spray twice, 10 days apart, starting as leaves unfold.
BOSTON IVY—See Ivy.			
BOXELDER—See Maple.			
BOXWOOD			
Canker or stem blight Fungus leaf blights or spots Anthracnose	copper[3] liquid lime-sulfur	See label 2 gal	Spray 4 times: (1) while dormant after old leaves have been cleaned up and before new growth starts; (2) 10 to 14 days later; (3) when growth is half complete; and (4) in autumn when fall growth has ceased.
Phytophthora root rot	etridiazole (Truban or Terrazole) metalaxyl (Subdue)[2] Banrot fosetyl-Al, 80% WP (Aliette)	4-10 oz/400 sq ft 1-4 oz/400-800 sq ft See label 1-2 lb/1,000 sq ft	Apply as drenches around plants to saturate the soil. Repeat at 4- to 12-week intervals in spring and autumn. Check label registrations.
Nematodes, including root-knot lesion	fenamiphos (Nemacur, 10G)[7]	180 lb/A	*For nursery stock:* Apply postplant and irrigate after application with 1/2 inch of water; only 1 application per year.
	Vydate 2L[7]	3-4 gal to 20 gal	*Preplant:* Incorporate 4 to 8 inches deep immediately after application. Use proportionately less material for band application.
	Vydate 2L drench	1 pt per 100 gal	*Pot drench*: Drench soil with mixture; 4 to 8 oz/6-inch pot or 2 to 4 oz/4-inch pot.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
BOXWOOD, cont.			
Nematodes	Vydate 2L foliar spray	2-4 pints per 100 gal	Apply as dilute spray, up to 8 pints/A. Apply on a 2- to 3-week schedule for 4 applications. Spray when plants are actively growing and not under stress. Use with a spreader-sticker.
	ethoprop (Mocap EC)[7]	1/2 pint per 100 gal	*Field nursery stock*: Apply 1 gal of mixture/sq yd. Avoid contact with foliage. Apply enough water to soak soil 4 to 6 inches deep.
		1/2-1 pint per 1,000 sq ft	*Bed and bench treatment:* Same as for field nursery stock (above).
		1/2 pint per 100 gal	*Pot drench*: Drench soil with mixture; 1/2 pint/6-inch pot or 1 pint/8-inch pot.
	Temik, 10G (SLN 8000-003)[8]	92-122 oz per 1,000 sq ft of row	Sidedress 3-4 inches deep 10-12 inches on each side of row.
BUCKEYE—See Horsechestnut.			
BUSH HONEYSUCKLE			
Fungus leaf spots	copper[3]	See label	Spray twice, 10 days apart, starting as the leaves unfold.
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 1/2-1 See label	Spray 2 or 3 times, 10 days apart. Start when mildew first appears.
BUTTERNUT—See Walnut.			
BUTTONBUSH			
Powdery mildew	benomyl, 50% WP sulfur, 80-95% WP Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 2-3 1/2 See label	Spray weekly several times. Start when disease first appears.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
BUTTONWOOD—See Sycamore.			
CATALPA			
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP sulfur, 80-95% WP Rubigan A.S., 11% L	1/2 1/2 2-3 See label	Spray when disease first appears. Repeat 10 and 20 days later.
Fungus leaf spots	copper[3]	See label	If severe, spray when leaves are unfolding, when leaves reach full size, and 2 weeks later.
CHERRY, PEACH, NECTARINE, PLUM, ALMOND, MAYDAY-TREE, CHERRY-PLUM, CHERRY-LAUREL			
Black knot	dodine, 65% WP maneb, 80% WP benomyl, 50% WP mancozeb, 80% WP Topsin M	1/2-1 1-1/2 to 2 1 1-1/2 See label	Spray as buds begin to swell. Repeat at pink bud, at full bloom, and 2 to 3 weeks later. Sanitation is important. Check label registrations.
Brown rot, blossom and twig blight	benomyl, 50% WP sulfur, 80-95% WP captan, 50% WP triforine (Funginex) Topsin M mancozeb, 80% WP Ornalin or Ronalin, 50% WP chlorothalonil	1/2-1 5-10 2 See label See label 1-1/2 1/4-1/2 See label	Spray when first blossoms open, during full bloom, and again at petal-fall. Thorough coverage is required. Check label registrations.
Nematodes	Dasanit, 15G	See label	Apply evenly and incorporate into top 2 to 4 inches. For pot mix, thoroughly mix 1.4 qt/cu ft into soil. For outdoor use only.
	Temik, 10G	28-37 oz per 1,000 sq ft	Broadcast under drip line and incorporate into soil. For trees under 6 ft, see Boxwood. Do not treat trees that are to bear fruit within 2 years.
Nematodes (cherry, peach)	Nemacur, 15G[8]	66.7-133.3 lb per A	Band or broadcast; incorporate into top 2 to 4 inches of soil.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
CHERRY, cont.			
Nematodes (flowering cherry, nursery stock)	Vydate 2L[7]	See label	See Boxwood.
	Nemacur, 10G[7]	See label	See Boxwood.
Nematodes (plum)	Vydate 2L	See label	See Boxwood.
Leaf blister or curl Plum pockets Witches'-broom	captan, 50% WP	2	Spray once in late fall or just before buds swell in early spring.
	liquid lime-sulfur	2-6 gal[b]	
	chlorothalonil	See label	
	dodine, 65% WP	1/2-1	
	mancozeb, 80% WP	1-1/2	
	copper[3]	See label	
Coccomyces leaf spot, blight, or shot-hole	benomyl, 50% WP[2]	1/2	Spray 4 times, 2 weeks apart. Start as buds are opening.
	dodine, 65% WP	1/2-3/4	
	captan, 50%	2	
	Topsin M	See label	
	chlorothalonil	See label	
Perennial or Valsa canker	benomyl, 50% WP	1/2-1	Delay pruning until buds open in spring. Spray just after pruning.
Powdery mildew	benomyl, 50% WP	1/2	Spray when mildew first appears. Repeat once or or twice at 7- to 10-day intervals.
	Karathane, 19.5% WP	1/2-3/4	
	sulfur, 80-95% WP	1-1/2 to 2	
	Topsin M	See label	
	Rubigan A.S., 11% L	See label	
Rust	sulfur, 80-95% WP	4-6	Spray several times, about 10 days apart. Start about 2 weeks after petal-fall.
Scab Shot-hole Fungus leaf spots	benomyl, 50% WP	1/2-1	Spray 3 to 5 times, 10 to 14 days apart, starting at petal-fall. Check label registrations.
	sulfur, 80-95% WP	3-6	
	Zyban, 75% WP	1-1/2	
	captan, 50% WP	2	
	Duosan, 75% WP	1-1/2	
	Topsin M	See label	
	chlorothalonil	See label	

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
CONIFERS—See Pine.			
COTONEASTER			
Fire blight	bordeaux mixture	2-6-100[3]	Apply during bloom at 5- to 7-day intervals if temperature is above 65°F.
Nematodes	Nemacur, 10G[7] Vydate 2L[7]	See label See label	See Boxwood. See Boxwood.
Scab	benomyl, 50% WP[2] dodine, 65% WP mancozeb, 80% WP	1/2-1 1/2-1 1-1/2	Apply in spring as buds start to swell and repeat 2 to 3 weeks later.
Fungus leaf spots Botrytis blight	benomyl, 50% WP maneb, 80% WP mancozeb, 80% WP	1/2-1 1-1/2 to 2 1-1/2	Spray several times 10 to 14 days apart starting at budbreak. Check label registrations.
Nematodes	Nemacur, 10G	See label	See Boxwood.
CRABAPPLE, APPLE, PEAR			
Cedar rusts (apple, hawthorn, and quince)	triforine (Funginex) chlorothalonil Zyban, 75% WP maneb, 80% WP mancozeb Bayleton, 25% WP Duosan, 75% WP Rubigan A.S., 11% L Dikar, 76.7% WP	See label See label 1-1/2 to 2 1-1/2 to 2 See label 2-4 oz[b] 1-1/2 to 2 4-12 oz[b] 1-1/2 to 2	Spray as new growth first appears and flower buds start to open. Repeat 3 or 4 more times at 7- to 10-day intervals or follow label directions and check registrations. (Also see Juniper.)
Scab Fungus leaf spots and fruit rots Sooty blotch and flyspeck	benomyl, 50% WP dodine, 65% WP captan, 50% WP maneb, 80% WP mancozeb Dikar, 76.7% WP Zyban, 75% WP Duosan, 75% WP chlorothalonil Rubigan A.S., 11% L triforine (Funginex) Topsin M	1 1/2-3/4 2 1-1/2 to 2 See label 1-1/2 to 2 1-1/2 to 2 1-1/2 to 2 See label 4-12 oz[b] See label See label	Spray when growth first appears. Repeat 4 more times, 7 to 10 days apart until two weeks after petal-fall. Thorough coverage of new growth is essential. Carefully read the manufacturer's labels and check registrations.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
CRABAPPLE, cont.			
Fire blight	streptomycin formulations	See label	Spray when 20 percent of blossoms are open and repeat at 5-to 7-day intervals during bloom. Then apply weekly for 5 or 6 weeks. Best control is obtained by spraying at night.
	copper[3]	See label	
Nematodes (crabapple)	Nemacur, 10G[7]	See label	See Boxwood.
(apple, nonbearing)	Nemacur, 15G	See label	See Cherry.
(apple, pear, non-bearing)	Vydate 2L[7]	See label	See Boxwood.
	Temik, 10G	See label	See Cherry.
Powdery mildew	triforine (Funginex)	See label	Spray when disease first appears or as leaves start to expand. Repeat 2 or 3 times, 7 to 14 days apart.
	benomyl, 50% WP[2]	1/2	
	sulfur, 80-95% WP	6-8	
	Karathane, 19.5%	1/2-3/4	
	Dikar, 76.7% WP	1-1/2 to 2	
	Bayleton, 25% WP	2-4 oz[b]	
	Duosan, 75% WP	1-1/2	
	Zyban, 75% WP	1-1/2	
	Rubigan A.S., 11% L	4-12 oz[b]	
Phytophthora crown rot	Ridomil	See label	For nonbearing (12 months) trees only.
CURRANT, ALPINE			
Anthracnose	benomyl, 50% WP	1	Spray 2 or 3 times, 10 to 14 days apart. Start at leaf emergence or when leaves are nearly expanded.
Fungus leaf spots	maneb, 80% WP	1 1/2-2	
	mancozeb, 80% WP	1-1/2	
Powdery mildew	benomyl, 50% WP	1/2-1	Apply when mildew first appears. Repeat 2 or 3 times at 7- to 14-day intervals.
	Karathane, 19.5% WP	1/2-1	
	Rubigan A.S., 11% L	3-5 fl oz[b]	
DOGWOOD			
Fungus leaf spots	chlorothalonil	See label	Spray just before flower bracts are fully ex-panded. In wet years, repeat 2 or 3 more times 10 to 14 days apart.
Leaf blotch	benomyl, 50% WP	1	
Anthracnose	maneb	See label	
Spot anthracnose	mancozeb	See label	
Flower and leaf blights	captan, 50% WP	2	
	Zyban, 75% WP	1-1/2	
	Duosan, 75% WP	1-1/2	

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
DOGWOOD, cont.			
Powdery mildew	benomyl, 50% WP[2] Bayleton, 25% WP Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 2-4 oz[b] 1/2-1 See label	Spray when mildew first appears. Repeat 7 to 10 days later if needed.
ELM			
Anthracnose Black leaf spot and other fungus leaf spots Twig blight	sulfur, 80-95% WP benomyl, 50% WP[2] copper[3] mancozeb	2-3 1 See label See label	Spray 3 times, 10 to 14 days apart. Start when the leaf buds break open. Sanitary measures are very important.
Dutch elm disease	metam or SMDC (Vapam Soil Fumigant)	See label	Treat soil when disease first appears to prevent transmission by root grafts. Follow label directions.
	methoxychlor	See label	Apply just before bud-break to prevent inoculation by elm bark beetles.
	Arbotect 20-S[4] MBC-phosphate-carbendazin[4] (formerly Lignasan BLP, now sold as Hopkins Correx Fungicide, Agway Elmosan, Pratt Elm Tree Noculate, Arboral Fungicide, and Lily/Miller Ulmasan)	See label See label	For protective treatment. Should be injected into elms more than 5 inches in diameter by a trained arborist before elms contract the disease or when trees are newly infected and wilt symptoms are less than 5 percent. Apply before the removal of diseased branches and when leaves approach full size.
EUONYMUS			
Fungus leaf spots Anthracnose Scab Botrytis blight	benomyl, 50% WP maneb, 80% WP mancozeb Duosan, 75% WP Zyban, 75% WP Chipco 26019, 50% WP chlorothalonil	1 1-1/2 to 2 See label 1-1/2 1-1/2 1-1/2 to 2 See label	Apply at budbreak or at first sign of disease. Spray 2 or 3 times at 7- to 10-day intervals. Sanitary measures are important. Check label directions and registrations.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
EUONYMUS, cont.			
Powdery mildew	Karathane, 19.5% WP	1/2	Apply at first evidence of disease. Repeat at 7- to 10-day intervals. Follow label directions.
	Bayleton, 25% WP	2-4 oz[b]	
	benomyl, 50% WP	1/2-1[b]	
	triforine (Funginex)	See label	
	Rubigan A.S., 11% L	See label	
Root rots Crown rot	Banrot	See label	Apply Banrot 40% WP at the rate of 6 to 12 oz in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Mix Banrot 8% granules into soil before planting. Retreat at 4- to 12-week intervals. Apply Chipco 26019 at transplant time.
	Chipco 26019, 50% WP	6 1/2 oz[b]	
Nematodes	Nemacur, 10G[7]	See label	See Boxwood.
	Vydate 2L[7]	See label	See Boxwood.
	Temik, 10G	See label	See Boxwood.
EVERGREENS—See Fir, Juniper, Pine, Yew.			
FIR			
Needle and twig blights Leaf casts	copper[3]	See label	Spray 2 or 3 times, 15 to 30 days apart, starting when new needles are half grown.
	mancozeb	See label	
Rusts	sulfur, 80-95% WP	3-5	Spray 2 or 3 times, 7 to 10 days apart. Start a week before rust usually appears.
	Bayleton, 25% WP	2-4 oz[b]	
	mancozeb, 80% WP	1-1/2	
Root rots	Banrot	See label	Apply 6 to 12 oz of 40% WP in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Work 8% granules into soil before planting. Re-treat at 4- to 12-week intervals.
Nematodes (Douglas fir)	Vydate 2L	See label	See Boxwood.
	Temik, 10G	See label	See Cherry.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
FIRETHORN—See Pyracantha.			
FORSYTHIA			
Fungus leaf spots	mancozeb, 80% WP maneb, 80% WP copper[3] Chipco 26019, 50% WP	1-1/2 1-1/2 to 2 See label 1-2	Apply at budbreak and repeat at 7- to 10-day intervals as needed to keep foliage protected in damp weather.
HAWTHORN, RED HAW			
Leaf blight Scab Other fungus leaf spots	captan, 50% WP benomyl, 50% WP[2] maneb, 80% WP mancozeb dodine, 65% WP chlorothalonil	2 1 1-1/2 to 2 See label 3/4 See label	Apply 3 or 4 sprays at 7- to 10-day intervals, starting in early June. Extend the schedule during rainy seasons. Sanitation is important. Paul's Scarlet and English hawthorns are very susceptible. Maneb, chlorothalonil, and mancozeb also control rusts.
Cedar rusts	Bayleton, 25% WP maneb, 80% WP mancozeb chlorothalonil Duosan, 75% WP Zyban, 75% WP	2-4 oz[b] 1-1/2 to 2 See label See label 1 1	Spray as new growth appears and flower buds start to open. Repeat 3 or 4 times at 7- to 10-day intervals.
Fire blight	streptomycin formulations	See label	Spray when 20 percent of blossoms are open and at 5- to 7-day intervals during bloom. Do not use streptomycin on *C. mollis*.
Powdery mildew	Karathane, 19.5% WP benomyl, 50% WP chlorothalonil Bayleton, 25% WP Duosan, 75% WP Zyban, 75% WP Rubigan A.S. 11% L	1/2-1 1/2 See label 2-4 oz[b] 1-1/2 1-1/2 See label	Spray twice, 10 days apart, starting when mildew first appears.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
HICKORY			
Anthracnose	benomyl, 50% WP[2]	1	Spray 3 or 4 times, 7
Fungus leaf spot	mancozeb, 80% WP	1-1/2	to 10 days apart, start-
or blotch	maneb, 80% WP	1-1/2 to 2	ing as buds break open.
Scab			Sanitation is important.
Spot anthracnose			
HOLLY			
Fungus leaf spots	chlorothalonil	See label	Apply 3 or 4 sprays at
Tar spot	benomyl, 50% WP	1	10- to 14-day intervals.
Anthracnose	maneb, 80% WP	1-1/2 to 2	Start as leaves begin
Spot anthracnose	mancozeb	See label	to unfold. Sanitary measures are important.
Leaf and twig blight and algae	copper[3]	See label	Spray 3 or 4 times, 10 days apart. Start with the first autumn rains.
Powdery mildew	sulfur, 80-95% WP	4-5	Apply when disease first
	benomyl, 50% WP	1/2	appears. Repeat at
	Karathane, 19.5% WP	1/2-1	7-day intervals as
	Bayleton, 25% WP	2-4 oz[b]	needed.
	Rubigan A.S., 11% L	See label	
Root rots	Banrot	See label	Apply 6 to 12 oz of 40% WP in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Mix 8% granules into soil before planting. Re-treat at 4- to 12-week intervals.
Nematodes	Nemacur, 10G[7]	See label	See Boxwood.
	Vydate 2L[7]	See label	See Boxwood.
	Temik, 10G	See label	See Boxwood.
	Mocap EC[7]	See label	See Boxwood.
HONEYSUCKLE			
Herpobasidium	copper[3]	See label	Apply several sprays 7
leaf blight	mancozeb	See label	to 10 days apart. Start
	maneb, 80% WP	1-1/2 to 2	when new growth appears. Only young leaves are infected.
Powdery mildew	benomyl, 50% WP	1/2	Spray 2 or more times at
	sulfur, 80-95% WP	4-5	weekly intervals. Start
	Karathane, 19.5% WP	1/2-1	when disease first
	Topsin M	See label	appears.
	Rubigan A.S., 11% L	See label	

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
HORSECHESTNUT, BUCKEYE			
Leaf blotch Fungus leaf spot or blotch Anthracnose Spot anthracnose	benomyl, 50% WP[2] mancozeb maneb, 80% WP dodine, 65% WP chlorothalonil	1 See label 1-1/2 to 2 1-2 See label	Spray 3 or 4 times, 10 to 14 days apart, starting as the buds begin to open. Thorough coverage is required for control. Resistant species are available.
Nematodes	Vydate 2L[7]	See label	See Boxwood.
HYDRANGEA			
Fungus leaf spots Rust	chlorothalonil Topsin M mancozeb	See label See label See label	Spray 3 times, 7 to 10 days apart. Start when new growth appears.
Botrytis leaf and flower blight or gray-mold	benomyl, 50% WP Botran, 75% WP chlorothalonil Ornalin, 50% WP Chipco 26019, 50% WP Topsin M mancozeb maneb, 80% WP	1/2-1 1-1/3 See label 1/2-1 1-2 See label See label 1-1/2	Spray when symptoms first appear. Repeat twice weekly during rainy periods. In storage, apply Exotherm Termil dust or Botran 75W. Check label directions.
Root and stem rots of potted plants	Banrot, 40% WP Truban or Terrazole + benomyl, 50% WP	6-12 oz[b] See labels 1	Drench established plants with mixture. Avoid overwatering. Check label directions and registrations.
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP Topsin M Rubigan A.S., 11% L	1/2 1/4-1/2 See label See label	Spray several times, 7 to 10 days apart. Start when disease first appears.
IVY, ENGLISH—See *1990 Plant Disease Control Guide: Flowers and Other Nonwoody Ornamentals,* Circular 1259.			
IVY, BOSTON AND VIRGINIA CREEPER			
Powdery mildew	benomyl, 50% WP sulfur, 80-95% WP Topsin M Rubigan A.S., 11% L	1/2 3-4 See label See label	Spray several times at 7- to 10-day intervals. Start when disease first appears.
Leaf spots	Duosan, 75% WP Zyban, 75% WP	1-1/2 1-1/2	Spray 3 times at weekly intervals. Start as new growth appears.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
JUNEBERRY—See Amelanchier.			
JUNIPER, REDCEDAR			
Rusts	Bayleton, 25% WP maneb, 80% WP mancozeb, 80% WP Duosan, 75% WP Zyban, 75% WP	2-4 oz[b] 1-1/2 to 2 1-1/2 1-1/2 1-1/2	Spray susceptible junipers 4 times, 10 to 20 days apart, starting in early July. Resistant species and cultivars are available.
Phomopsis twig blight	benomyl, 50% WP[2] Zyban, 75% WP Duosan, 75% WP Cleary 3336 mancozeb	1 1-1/2 1-1/2 See label See label	Spray several times at 2-week intervals. Keep new flushes of growth protected. Resistant species are available.
Cercospora needle blight	copper[3] benomyl, 50% WP mancozeb, 80% WP	See label 1 1-1/2	Spray when disease first appears or after June 1. Repeat at 7- to 10-day intervals.
Root rots	Banrot	See label	Apply 6 to 12 oz of 40% WP in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Mix 8% granules into soil before planting. Re-treat at 4- to 12-week intervals.
Nematodes (including lesion)	Nemacur, 10G[7] Vydate 2L[7] Dasanit, 15G[7] Temik, 10G	See label See label See label See label	See Boxwood. See Boxwood. See Boxwood. See Boxwood.
LILAC			
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP triforine (Funginex) Bayleton, 25% WP Milban, 39% EC Duosan, 75% WP Zyban, 75% WP Topsin M Rubigan A.S., 11% L	1/2 1/2 See label 2-4 oz[b] See label 1-1/2 1-1/2 See label See label	Spray several times at 2-week intervals. Start when disease first appears, usually in July. Milban is a restricted-use pesticide.
Bacterial and Phytophthora blights	copper[3]	See label	Spray 2 or 3 times at 7- to 10-day intervals. Start when new growth appears in spring.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
LINDEN, BASSWOOD			
Anthracnose Fungus leaf spots Leaf blight Spot anthracnose	copper[3] benomyl, 50% WP[2]	See label 1	Spray just after bud-break and again 10 and 20 days later. Sanitary measures are important.
Powdery mildew	benomyl, 50% WP sulfur, 80-95% WP	1/2 4-6	Spray when mildew first appears. Repeat 10 days later.
MAGNOLIA			
Powdery mildew	benomyl, 50% WP Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 1/2-1 See label	Spray 2 or 3 times, 7 to 10 days apart. Start when disease first appears.
Fungus leaf spot Leaf blight	copper[3]+ benomyl, 50% WP mancozeb	See label 1/2-1 See label	Spray twice, 10 days apart. Start as buds break open.
Nematodes	Vydate 2L[7]	See label	See Boxwood.
MAPLE, BOXELDER			
Anthracnose Fungus leaf spots Leaf blight or blotch Leaf scab Tar spot Leaf blister	mancozeb maneb, 80% WP benomyl, 50% WP chlorothalonil captan, 50% WP Duosan, 75% WP Zyban, 75% WP	See label 1-1/2 to 2 1 See label 2 1-1/2 1-1/2	Spray 3 or 4 times, 10 days apart, starting as buds begin to open. For tar spot, spray just before the buds swell in early spring. Sanitation is important.
Nematodes (sugar maple)	Vydate 2L Temik, 10G	See label See label	See Boxwood. See Cherry.
Root rots	Banrot	See label	Treat in seed bed and nursery bed. Follow label directions.
MAYDAY-TREE—See Cherry.			
MOUNTAIN-ASH			
Leaf blight and scab Fungus leaf spots	benomyl, 50% WP mancozeb maneb, 80% WP chlorothalonil	1 See label 1-1/2 to 2 See label	Spray 2 to 4 times, 10 days apart, starting as the leaf buds open.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
MOUNTAIN-ASH, cont.			
Rusts	mancozeb, 80% WP	1-1/2	Spray 4 to 5 times, 10 days apart. Start as flower buds begin to open.
Fire blight	streptomycin formulations copper[3]	See label See label	Spray when 20 to 25 percent of blossoms are open and again at full bloom.
MULBERRY			
Bacterial blight or leaf spot Fungus leaf spot False mildew	bordeaux mixture copper[3]	5-5-100[3] See label	Apply at budbreak and repeat at 7-day intervals during moist periods. If severe, spray twice, 10 days apart, starting as the leaves unfold.
Powdery mildew	benomyl, 50% WP[2] Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 1/2-1 See label	Spray twice, 10 days apart. Start when mildew first appears.
Nematodes	Vydate 2L[7]	See label	See Boxwood.
NECTARINE—See Cherry.			
OAK			
Anthracnose[5] Fungus leaf spots and blights Spot anthracnose Leaf blotch Leaf blister	chlorothalonil copper[3] benomyl, 50% WP dodine, 65% WP mancozeb maneb, 80% WP	See label See label 1 1 See label 1-1/2 to 2	Spray 3 times: (1) just before buds open; (2) when leaves are half grown; and (3) 10 to 14 days later. Follow label directions. Sanitary measures are important.
Oak wilt	fuel oil or fuel oil + ammonium sulfate (Ammate)	See label	Apply to deep girdle and axe cuts in roots to the point of runoff before tree wilts 50 percent. Treatment kills infected trees and prevents disease spread to healthy oaks.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
OAK, cont.	metam or SMDC (Vapam Soil Fumigant)	See label	When disease first appears, treat soil, to prevent transmission to nearby healthy oaks through root grafts. Follow label directions.
PEACH—See Cherry.			
PECAN Scab Fungus leaf spots Leaf blotch and scorch Spot anthracnose Anthracnose Sooty mold	benomyl, 50% WP[2] maneb, 80% WP mancozeb, 80% WP dodine, 65% WP Du-Ter Topsin M	1 1-1/2 to 2 1-1/2 1/2-1 See label See label	Apply 4 to 6 sprays, 10 to 14 days apart. Start when buds begin to open. Thorough coverage is required. Follow manufacturer's directions.
Powdery mildew	benomyl, 50% WP[2] Du-Ter Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 See label 1/2-1 See label	Spray when mildew is first seen. Repeat at 10- to 14-day intervals.
PHOTINIA Powdery mildew Entomosporium leaf spot	benomyl, 50% WP[2] sulfur, 80-95% WP triforine (Funginex), 18.2% Bayleton, 25% WP Topsin M Duosan, 75% WP Zyban, 75% WP chlorothalonil mancozeb	1 4-6 16 fl oz[b] 4-8 oz[b] See label 1-1/2 1-1/2 See label See label	Spray several times at 7- to 14-day intervals. Start when new leaf growth or disease first appears. Check label registrations. Mancozeb will not control powdery mildew.
PINE Dothistroma needle blight	copper[3]	See label	Spray twice: when new needles are just emerging and when new needles are fully expanded 6 to 8 weeks later.
Scirrhia brown spot and needle blight	copper[3] mancozeb maneb, 80% WP chlorothalonil	See label See label 1-1/2 See label	Spray once or twice, 30 days apart, starting when new needles are half-grown. If rainy, spray at 2-week intervals.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
PINE, cont.			
Lophodermium needle cast or blight	mancozeb maneb, 80% WP chlorothalonil benomyl, 50% WP[2]	See label 4 See label 1-1/2 to 2	Spray 4 times, 2 to 3 weeks apart, starting in early July when the new needles are fully grown.
Sphaeropsis or Diplodia tip blight or dieback	copper[3] benomyl, 50% WP[2] mancozeb chlorothalonil	See label 1 See label See label	Spray 3 or 4 times, 10 to 14 days apart. Start just before budbreak.
Scleroderris or Gremmeniella canker	chlorothalonil	See label	Spray as new growth appears in spring. Repeat at 2-week intervals until early July, then monthly until early September.
Soil nematodes	Nemacur, 10G[7] Vydate 2L[7]	See label See label	See Boxwood. See Boxwood.
Pine Wilt	None	See label	Remove tree and other dead pines in area. Destroy dead wood immediately.
Annosus root and butt rot	borax, 100% (dry, powdered)	1 lb per 50 sq ft of stump surface[b]	Cover fresh-cut stump surface immediately after felling tree. Sprinkle liberally and evenly.
Cylindrocladium blight	benomyl, 50% WP Cleary 3336 Topsin M	1 See label See label	Apply as a soil drench to seedling beds at 2- to 4-week intervals.
Damping-off Root rot Rhizoctonia needle blight	etridiazole (Truban or Terrazole) Banrot	See label See label	Drench around plants in nursery beds at 2- to 12-week intervals or mix Banrot or etridiazole granules into soil before planting.
	PCNB (Terraclor) + metalaxyl[2] (Subdue or Ridomil)	See label See label	Apply at a 1:16 ratio to nursery beds prior to seeding; may also apply metalaxyl as a broadcast spray.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
PLANETREE—See Sycamore.			
PLUM—See Cherry.			
POPLAR			
Leaf rusts	triforine (Funginex) mancozeb, 80% WP maneb, 80% WP sulfur, 80-95% WP Bayleton, 25% WP	See label 1-1/2 2 4-6 2-4 oz[b]	Spray in early summer about a week before rust is expected and again 10 to 14 days later.
Yellow leaf blister	mancozeb, 80% WP maneb, 80% WP	1-1/2 2	Apply several weekly sprays starting when spots first appear on the lower leaves.
Powdery mildew	sulfur, 80-95% WP benomyl, 50% WP[2] Bayleton, 25% WP Rubigan A.S., 11% L	4-1/2 to 5-1/2 1/2 2-4 oz[b] See label	Apply at first sign of disease. Repeat 2 or 3 times at 5- to 10-day intervals.
PRIVET			
Anthracnose Fungus leaf spot Twig blight	benomyl, 50% WP[2] Bayleton, 25% WP chlorothalonil mancozeb Topsin M, 70% WP	1 2-4 oz[b] See label See label See label	Spray several times at 10-day intervals starting in mid-spring.
Powdery mildew	Bayleton, 25% WP benomyl, 50% WP Karathane, 19.5% WP sulfur, 80-95% WP Rubigan A.S., 11% L	2-4 oz[b] 1/2 1/2 3-5 See label	Spray twice, 10 days apart. Start when mildew appears.
Root rots Stem rots Damping-off	Banrot	See label	Apply 6 to 12 oz of 40% WP in 100 gal water to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Mix 8% granules into soil before planting. Re-treat at 4- to 12-week intervals.
Nematodes	Dasanit, 15G[7] Vydate 2L[7]	See label See label	See Boxwood. See Boxwood.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
PYRACANTHA, FIRETHORN			
Fire blight	streptomycin formulations copper[3]	See label See label	Spray when 20 to 25 percent of blossoms are open and repeat at 5- to 7-day intervals during bloom.
Scab	benomyl, 50% WP[2] chlorothalonil mancozeb Duosan, 75% WP Zyban, 75% WP Topsin M Cleary 3336	1 See label See label 1-1/2 1-1/2 See label See label	Spray 4 times: (1) at budbreak; (2) just before blossoms open; (3) at petal-fall; and (4) 2 weeks later. Add a spreader-sticker to the spray mix.
Nematodes	Nemacur, 10G[7] Vydate 2L[7] Dasanit, 15G[7]	See label See label See label	See Boxwood. See Boxwood. See Boxwood.
QUINCE			
Fire blight	bordeaux mixture	2-6-100[3]	Spray when 20 percent of blossoms are open. Repeat when 75 percent are open. Do not use streptomycin on quince.
Rust Scab Fungus leaf spots	maneb, 80% WP mancozeb, 80% WP chlorothalonil	1-1/2 to 2 1-1/2 See label	Apply several sprays at 10-day intervals starting at budbreak.
REDBUD			
Cercospora and other fungus leaf spots	copper[3] maneb, 80% WP mancozeb, 80% WP	See label 1-1/2 to 2 1-1/2	If serious, apply at budbreak and repeat several times at 10-day intervals during spring rainy periods.
Botryosphaeria canker	benomyl, 50% WP		Treat wounds and pruning scars with 1/2 t benomyl in 1 gal of tree-wound dressing.
REDCEDAR—See Juniper.			
RED HAW—See Hawthorn.			

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
RHODODENDRON, AZALEA			
Ovulinia petal or flower blight of azalea	Ziram Zyban, 75% WP benomyl, 50% WP[2] mancozeb chlorothalonil Bayleton, 25% WP Duosan, 75% WP Topsin M triforine (Funginex)	See label 1-1/2 1/2 See label See label 1/4-1/2 1-1/2 See label See label	Spray as flowers begin to open. Then apply benomyl at 5-day intervals. Or apply mancozeb 3 times weekly during bloom. See labels for details.
Powdery mildew	benomyl, 50% WP Karathane, 19.5% WP Bayleton, 25% WP Topsin M Rubigan A.S., 11% L	1/2 1/2-1 2-4 oz[b] See label See label	Spray several times at 7- to 14-day intervals. Start when disease first appears.
Fungus leaf spots Rusts Leaf, flower, and stem galls	maneb, 80% WP mancozeb benomyl, 50% WP[2] chlorothalonil	1-1/2 to 2 See label 1/2-1 See label	Spray several times at 10-day intervals. Start at budbreak. Benomyl is not effective against rusts.
Bud and twig blight Dieback	copper[3] chlorothalonil benomyl, 50% WP[2]	See label See label 1/2-1	Spray 3 times, 7 to 10 days apart, starting at budbreak.
Root and crown rot and dieback Wilt (*Phytophthora cinnamomi* and other fungi)	etridiazole (Truban or Terrazole) Banrot, 40% WP metalaxyl (Subdue)[2] fosetyl-Al, 80% WP (Aliette) propamocarb (Banol)	See label 6-12 oz[b] See label 6 1/2-13 oz/ cu yd See label	Apply as a drench around plants to saturate the soil. Repeat at 3- to 12-week intervals in spring and autumn. Or blend granules into soil just before planting. Follow label directions.
Nematodes	Dasanit, 15G[7] Nemacur, 10G[7] Vydate 2L[7] Mocap EC[7] Temik 10G	See label See label See label See label See label	See Boxwood. See Boxwood. See Boxwood. See Boxwood. See Boxwood.
Cutting rot or dieback Cylindrocladium root rot	benomyl, 50% WP Topsin M etridiazole (Truban or Terrazole) Cleary 3336	See remarks See label See label See label	Mix 1 part benomyl with 39 parts of root-inducing hormone powder by weight. Treat cut ends with mixture before sticking in rooting medium. Then drench soil as for root and crown rot or wilt. Apply etridiazole as for root and crown rot or wilt.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
ROSE			
Botrytis blight	benomyl, 50% WP[2]	1/2-1	Mist flowers at 7- to 10-day intervals in moist weather. Do not apply Ornalin immediately after yearly cutback. Ornalin and Botran may be used as a post harvest cut flower, budwood, or bareroot nursery stock dip in cold storage or transit.
	Botran, 75% WP	1/2-3/4	
	Ornalin, 50% WP	1 to 1-1/2	
	Chipco 26019, 50% WP	1-2	
	Duosan, 75% WP	1-1/2	
	Zyban, 75% WP	1-1/2	
	chlorothalonil	See label	
	Cleary 3336	See label	
	mancozeb, 80% WP	3/4	
Black spot	triforine (Funginex), 18.2% EC	12-18 fl oz	Spray at 7- to 10-day intervals starting when new growth appears. Shorten spray interval to 5 or 7 days in rainy weather. Maneb, mancozeb, triforine, and chlorothalonil also control rusts.
Cane blight	chlorothalonil	See label	
Cankers	maneb	See label	
Spot anthracnose	mancozeb	See label	
Anthracnose	benomyl, 50% WP	1	
Fungus leaf spots	Zyban, 75% WP	1-1/2	
Rusts	Duosan, 75% WP	1-1/2	
	Topsin M	See label	
	Ziram	See label	
Powdery mildew	benomyl, 50% WP	1/2	Spray at 7- to 14-day intervals starting when new growth appears. Thorough coverage is required. Follow label directions. Milban is a restricted-use pesticide. Pipron is for use only in commercial greenhouses.
	Karathane, 19.5% WP	1/2	
	Bayleton, 25% WP	1-4 oz[b]	
	Milban, 39% EC	32 oz[b]	
	triforine (Funginex), 18.2% EC	12-18 fl oz[2]	
	Zyban, 75% WP	1-1/2	
	Duosan, 75% WP	1-1/2	
	Rubigan A.S. 11% L	4 to 12 oz[2]	
	Pipron, 82.4% L	1/4 pt	
Fungus leaf spots	copper[3]	See label	Spray twice, 10 days apart, starting as leaves unfold. Thorough coverage is required.
	Bayleton, 25% WP	2-4 oz[b]	
	Zyban, 75% WP	1-1/2	
	Duosan, 75% WP	1-1/2	
	mancozeb	See label	
Nematodes	Dasanit, 15G[7]	See label	See Boxwood.
	Nemacur, 10G[7]	See label	See Boxwood.
	Vydate 2L[7]	See label	See Boxwood.
	Temik, 10G	See label	See Boxwood.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
RUSSIAN-OLIVE			
Fungus leaf spots	copper[3] Bayleton, 25% WP	See label 2-4 oz[b]	Spray twice, 10 days apart, starting as leaves unfold.
SERVICEBERRY, SHADBUSH—See Amelanchier.			
SPRUCE—See Pine.			
SUMAC			
Fungus leaf spots	maneb, 80% WP sulfur, 80-95% WP mancozeb, 80% WP	1-1/2 to 2 4-6 1-1/2	Apply when disease is first seen. Repeat as needed at 7- to 10-day intervals during rainy periods.
SYCAMORE, PLANETREE, BUTTONWOOD			
Anthracnose[5] Fungus leaf spots Leaf blight	chlorothalonil benomyl, 50% WP[2] copper[3] mancozeb, 80% WP maneb, 80% WP dodine, 65% WP Duosan, 75% WP Zyban, 75% WP	See label 1 See label 1-1/2 1-1/2 to 2 1 1-1/2 1-1/2	Spray 3 times: (1) just before buds break open; (2) at budbreak; and (3) when leaves are expanded, 10 to 20 days later. Thorough coverage is required. Check label directions.
Powdery mildew	benomyl, 50% WP sulfur, 80-95% WP Bayleton, 25% WP Rubigan A.S., 11% L	1/2 4-6 2-4 oz[b] See label	Spray 2 or 3 times, 7 to 10 days apart, starting when disease first appears.
Canker stain	benomyl, 50% WP	See remarks	Add 1/2 t per gal to asphalt-base tree wound dressing.
TAXUS—See Yew.			
TULIPTREE			
Fungus leaf spots	copper[3]	See label	If severe, spray 2 or 3 times, 10 days apart. Start at budbreak.
Powdery mildew	benomyl, 50% WP Karathane, 19.5% WP Rubigan A.S., 11% L	1/2 1/2-1 See label	If severe, spray twice, 10 days apart, starting when mildew first appears.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
VIBURNUM			
Powdery mildew	benomyl, 50% WP[2]	1/2	Spray 2 or more times,
	Karathane, 19.5% WP	1/2	7 to 10 days apart.
	Bayleton, 25% WP	2-4 oz[b]	Start when disease first
	chlorothalonil	See label	appears.
	Rubigan A.S., 11% L	See label	
Nematodes	Nemacur, 10G[7]	See label	See Boxwood.
	Vydate 2L[7]	See label	See Boxwood.
	Dasanit, 15G[7]	See label	See Boxwood.
	Temik, 10G	See label	See Boxwood.
VIRGINIA CREEPER—See Ivy.			
WALNUT, BUTTERNUT			
Anthracnose	benomyl, 50% WP[2]	1	Spray 3 or 4 times at
Yellow leaf blotch	dodine, 65% WP	1	2-week intervals starting
Fungus leaf spots	mancozeb	See label	when the leaves begin to
or blights	maneb, 80% WP	1-1/2 to 2	unfold. Thorough
	Duosan, 75% WP	1-1/2	coverage is required.
	Zyban, 75% WP	1-1/2	
Bacterial blight (of Persian or English walnut)	copper[3]	See label	Spray 4 times: (1) when flowering starts; (2) at full bloom; (3) at petal-fall; and (4) 7 to 10 days later.
	streptomycin formulations	See label	
WILLOW			
Tar spot	copper[3]	See label	Spray 3 times, 10 days
Leaf blight	mancozeb, 80% WP	1-1/2	apart, starting as the
Scab	maneb, 80% WP	1-1/2 to 2	buds open. Maneb,
Black canker	dodine, 65% WP	1/2-1	and mancozeb also con-
Spot anthracnose			trol rust. Sanitary measures are important.
Powdery mildew	sulfur, 80-95% WP	4-6	Apply 2 or more times,
Rust	Bayleton, 25% WP	2-4 oz[b]	7 to 10 days apart. Start when disease first appears.
WITCHHAZEL			
Powdery mildew	benomyl, 50% WP[2]	1/2	Spray 2 or more times,
	Karathane, 19.5% WP	1/2-1	7 to 10 days apart.
	sulfur, 80-95% WP	3-4	Start when disease first
	Rubigan A.S., 11% L	See label	appears.
Fungus leaf spots	copper[3]+ benomyl, 50% WP	See label / 1/2-1	If severe, spray twice, 10 days apart. Start as leaves begin to unfold.

See footnotes at the end of Table 2.

Plant and disease	Suggested fungicides or nematicides[a]	Rate, pounds per 100 gallons[1]	Application and remarks[b]
YEW (*Taxus*) Twig blight	bordeaux mixture	4-4-100[3]	Apply when new growth emerges. Repeat twice more at 7- to 10-day intervals.
Phytophthora root rot	Aliette, 80% WP etridiazole (Truban or Terrazole)	See label See labels	Apply as a soil drench. Follow label directions.
Nematodes	Nemacur, 10G[7] Mocap EC[7] Dasanit, 15G[7] Vydate 2L[7]	See label See label See label See label	See Boxwood. See Boxwood. See Boxwood. See Boxwood.
ALL WOODY PLANTS Seed decay Damping-off Seedling blights	thiram, 42-75% WP captan, 50% WP	See remarks See remarks	Apply 2 oz per lb of seed. If damping-off starts, drench seedbed at 4 T per gal when first seen. Follow label directions.
Root rots Nematodes	methyl bromide methyl bromide 2:1 + chloropicrin mixtures Vorlex Vapam	See label See labels See label See label	Apply under gas-proof cover several weeks prior to planting in nursery beds. Controls damping-off, root rots, and nematodes.
	etridiazole (Truban or Terrazole) Banrot, 40% WP metalaxyl (Subdue)[2] fosetyl-Al, 80% WP (Aliette)	See labels See label See label See label	Apply as a soil drench after plants are set. Repeat at 2- to 12-week intervals. Etridiazole, fosetyl-Al, and metalaxyl control only *Phytophthora* and *Pythium*. May be combined with captan or thiram. Follow label directions.
Wood rots or decays	thiram, 75% WP benomyl, 50% WP	1 1/4	Apply thinly in an asphalt or other nonfortified tree wound preparation. See also remarks on Sanitation preceding Table 2. Dip tools in 70% denatured alcohol or 4% formaldehyde to disinfect them between working on trees.

See footnotes at the end of Table 2.

Footnotes

1 The rates given are based on hydraulic application and are expressed in pounds per 100 gallons unless specified otherwise. If using a mistblower, follow label directions.
2 Whenever possible, benomyl and metalaxyl should be alternated with another fungicide or mixed with it to avoid development of resistant strains or races of fungi.
3 Copper fungicides include fixed or neutral copper compounds and bordeaux mixtures, usually 4-4-100 or 88-100. The first number in a bordeaux mixture refers to pounds of copper sulfate, the second refers to pounds of hydrated spray lime, and the third refers to gallons of water.
4 Arbotect 20-S and MBC-phosphate or carbendazin materials have not been fully tested by specialists in tree pathology. Therefore, they cannot be recommended without reservations. The products should be used by trained arborists and others acquainted with the identification of Dutch elm disease and with injection techniques. Infection through trunk wounds has led to woodstain and decay.
5 Treatments listed are recommended for the leaf-blight stage of anthracnose only.
6 Do not try to remove rotted, soft tissues in order to fill cavities. Internal wounds break decay-resistant barriers, so avoid boring holes through sound wood into rotted wood. Callus may close the outer opening, but the plant cannot close the inner opening. Decay fungi can thus pass the natural barrier.
7 For commercial use only. Restricted use, only for application by certified applicators or operators.
8 SLN 8000-003 is a state local need number (Illinois only).

[a]WP = wettable powder; EC = emulsifiable concentrate; G = granular; L = liquid.
[b]gal = gallon(s); sq ft = square foot(feet); oz = ounce(s); lb = pound(s); ai = active ingredient.

1990 Plant Disease Control Guide:

FLOWERS and NONWOODY ORNAMENTALS

Disease control programs for flowers and other nonwoody ornamentals should be based on a thorough knowledge of the diseases that are likely to appear and the plants that are susceptible to attack and on an early and accurate diagnosis of the problem. Control measures *must* start before or at the early onset of disease, but preferably before symptoms appear. Disease control programs should begin with the purchase of the best seed or planting materials available and continue throughout the season until the plants or their parts are sold or discarded.

Traditionally, four fundamental principles apply to plant disease control. The four may be applied individually or concurrently for integrated control of infectious agents or pathogens. These principles are exclusion, eradication, immunization, and protection. All cultural and chemical practices that are used to keep plants from becoming diseased can be placed into one of these four categories.

Exclusion involves preventing the disease-causing organisms and agents from becoming established in or around susceptible plants. Exclusion is achieved through federal or state embargoes, quarantines, inspections, and disinfection of plants, seeds, cuttings, bulbs, corms, and other propagative plant parts. Other methods include certification of plants, cuttings, and seed before shipment and culture indexing of planting stock to ensure freedom from pathogens.

Eradication is the elimination of the disease-causing agent or pathogen after it has become established in or on a plant where it is growing or being stored. Eradication involves the removal and destruction of infected plant parts, diseased plants, infected debris, weeds, alternate hosts, and other overwintering host plants. It also involves seed or plant treatment with wet or dry heat or a systemic chemical; crop rotation; treatment of the soil or other medium with heat or an eradicative chemical such as a multipurpose soil fumigant; and cleaning and disinfesting potting benches, soil bins, greenhouse benches, nursery beds, storage areas, tools, and equipment.

Immunization involves growing resistant or immune species, varieties, or cultivars and treating the disease with a systemic chemical that internally kills, inactivates, or protects against infection. Unfortunately, there are no ornamental plants resistant or immune to all diseases. Much less time and effort has been put into developing disease resistance in flowers and nonwoody ornamentals than into field crops, vegetables, and fruits.

Protection is the placing of a physical or chemical barrier between the susceptible part of the host plant and the disease agent or pathogen. Protection usually means uniform applications of recommended disease-control chemicals, including fungicides, bactericides, or nematicides, as dusts, sprays, or soil drenches. Chemicals should be applied to the plant or its propagative parts *before* the pathogen arrives.

Protective cultural practices include proper spacing of plants; time and depth of planting; proper soil reaction (pH); careful handling of plants and propagative parts during harvest, grading, and packing; proper lighting, temperature control, watering, fertilization, and pruning; and the alteration of the air and soil environment to make it unfavorable for the pathogen to infect, develop, reproduce, or spread during growth, storage, and shipment.

Prepared by **M. C. Shurtleff,** Extension Plant Pathologist.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
COOPERATIVE EXTENSION SERVICE
CIRCULAR 1259-90 (revised annually)

COLLEGE OF AGRICULTURE
November 1989

To be successful, the right chemical must be applied at the right concentration, at the right time, and in the right way. Correctly applying the proper chemicals ensures an active and complete chemical barrier on the susceptible plant surface during the time when infection may occur. Several applications, spaced about 7 to 10 days apart for protective fungicides and 10 to 21 days or longer for systemic fungicides, are usually needed to keep expanding foliage and flowers covered with a protective film.

Protection also includes the killing of insects, mites, and other inoculating agents before these pests can feed and infect plants with pathogens carried on or in their bodies. Some seed treatments, such as captan, thiram, and Apron are protective against seed- and soilborne organisms.

To help in diagnosing the common diseases of flowers and other nonwoody ornamentals, a key to their identification is presented in Table 1. The symptoms in the key are divided into those that appear on the leaves, stems and branches, flowers, and underground parts.

The pesticides listed in Tables 2 and 3 are presented by their common and trade names as much as possible. The percentage of active ingredients and formulation information are presented adjacent to these names. Various formulations of common fungicides, such as Truban, are available: wettable powders (WP), emulsifiable concentrates (EC), and granules (G). The fact that Truban 25% EC is cleared for use on Chamaedora palm, for example, does not mean that the 30% WP, or the 5% G formulations are also legal to use on this species. Specific formulations differ in percentages of active ingredient and, therefore, in efficacy and crop safety.

Some common fungicides such as zinc ion and maneb complex (mancozeb) are often available under several major trade names. For example, DuPont's Manzate 200 and Rohm & Haas's Dithane M-45 labels list the same percentages of active ingredient, yet Manzate 200 is legal to use on a number of ornamentals while Dithane M-45 is not. Rohm & Haas's Fore is the equivalent of Dithane-45 for use on ornamentals. Always read and follow label directions and precautions. Use the product only on the plants listed on the label. It is illegal to do otherwise.

This publication presents the disease control application intervals and rates for various crops as approved by the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA) as of September 1, 1989, to the best of our knowledge.

Label registrations can change at any time. Thus, the recommendations in this circular may become invalid. The user is encouraged to carefully read and follow the most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Fertilization

Unthrifty and undernourished flowers and nonwoody ornamentals are susceptible to a variety of diseases and environmental stresses. Their vigor can often be greatly improved by having a soil test made prior to planting and following suggestions in the report.

Sanitation

Proper selection of planting site, planting method (depth and spacing), and plant materials as well as soil preparation, disease, insect, and weed control, and avoidance of unnecessary wounding will all aid in control of a wide range of diseases.

Watering

Ornamental plants should receive the equivalent of an inch of water as rainfall or supplemental irrigation each week during the growing season. If irrigating, apply water in the morning on a rising temperature, not during late afternoon or evening. Where possible use a soaker hose rather than overhead watering. Try to keep water off the foliage.

NOTE: The information in the following tables is for educational purposes only. Reference to commercial products or trade names does not constitute an endorsement by the University of Illinois and does *not* imply discrimination against other similar products. Trade names are presented for reasons of clarity only. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

Table 1. Disease Symptoms of Flowers and Nonwoody Ornamentals

General symptoms	Specific symptoms	Disease
LEAVES		
Leaves show small to large, definite spots that vary in size, shape, and color.	Small, dark specks are present, indicating fungal fruiting bodies; spots often roundish with dark margins.	Fungus leaf spot Scab Spot anthracnose
	Dark, water-soaked angular spots in leaves; spots later turn gray, brown, reddish-brown, or black; margins usually water-soaked.	Bacterial leaf spot or blight
	Irregular, often large, dead areas in leaves.	Leaf blight or blotch Anthracnose
Leaves spotted or blighted; later covered with dusty mold growth.	Tan to gray, coarse mold.	Botrytis blight or gray-mold
	White to light gray mold.	
	Powdery to mealy; easily wiped off.	Powdery mildew
	Powdery, white raised pustules on underleaf surface; may later turn yellow, then brown.	White rust
	Light gray to pale purplish downy growth on underleaf surface.	Downy mildew
	Black mold.	
	Sooty or crusty; easily wiped off.	Sooty mold or blotch
	Sooty mold inside "blisters" or galls.	Smut
	Yellow, orange, reddish-orange, reddish-brown, chocolate brown, or black mold in raised pustules.	Rust
Leaves with yellow to brown or black angular spots; plants stunted or bushy.		Foliar nematodes

General symptoms	Specific symptoms	Disease
LEAVES, cont. Leaves mottled light and dark green or yellow; often stunted, curled, and crinkled.	May form an irregular light and dark green mosaic or mottled pattern.	Mosaic Mottle Crinkle Streak
	Yellow-green or reddish-brown rings, "oakleaf," "watermark," or line patterns in leaves.	Ringspot or spotted wilt
Leaves and shoots stunted or dwarfed and erect; appear "bunchy"; younger parts uniformly yellow, sometimes red or purple.		Yellows Dwarf Stunt
Leaves wilt, wither, and die; may involve part or all of plant.	Discoloration inside lower stem.	Wilt disease
	Leaves wilt, wither, and die from stem or crown rot, root rot, drought or excess water, transplant shock, injury from insects or other animals, fertilizer or pesticide injury, an excess of soluble salts, frost, other mechanical injuries.	Miscellaneous diseases and injuries
STEMS AND BRANCHES Plants lack vigor; leaves are small and pale, may later wilt or turn yellow.	Seedlings collapse and die; stand is poor.	Damping-off Seed rot
	Stems of older plants are water-soaked or discolored and decayed, often just at the base.	Stem or crown rot
	Stems or branches show definitely marked, discolored, often sunken dead areas; parts beyond may wither and die.	Canker or dieback
	Shoots are often dwarfed or aborted; leaves are distorted; cauliflowerlike growth may appear at the soil line.	Leaf gall or fasciation

General symptoms	Specific symptoms	Disease
STEMS AND BRANCHES, cont.	Rough, swollen gall, either flesh-colored, greenish, or dark, usually found at or near the soil line.	Crown gall
FLOWERS		
Flowers are spotted, often wither or rot; may be covered with mold growth.		Flower or blossom blight
Flowers are blotched or streaked with white or yellow.		Mosaic or flower breaking
Flowers are greenish-yellow, dwarfed, aborted, or absent.		Aster yellows
ROOTS, BULBS, CORMS, AND TUBERS		
Plants lose vigor, often are stunted; may turn pale or yellow; tops may wilt and die back.	Roots decay; feeder roots die back; may be covered with mold.	Root rot
	Bulb, corm, or tuber decays; may be covered with mold.	Bulb, corm, or tuber rot
	Rough, roundish galls form on roots, corms, or tubers.	Crown gall
Root damage	Lack of hairy roots; root browning or galling.	Nematodes

Table 2. General Instructions for Most Ornamentals

Disease	Chemicals for control	Remarks
Damping-off Seed rot or decay Seedling blights	captan, metalaxyl (Subdue), etridiazole (Truban or Terrazole), Banrot, or iprodione (Chipco 26019)	Apply captan as a seed treatment any time before planting. Grow plants in sterilized (pasteurized) soil wherever feasible. Iprodione, metalaxyl, Banrot, and etridiazole are mixed into soil or applied as drenches. Check labels for crop rates and registrations.
Storage decay	captan, Botran, benomyl, or vinclozolin (Ornalin)	Spray, dust, or dip plants, bulbs, tubers, corms, and other plant parts before shipping or placing in storage. Check labels for crop registrations.
Cutting rots Damping-off Seedling blights Crown (foot) and stem rots Root rots	PCNB (Terraclor), captan-PCNB mixtures, Banrot, benomyl (Benlate), PCNB-etridiazole (SA Terraclor Super-X), thiophanate-methyl (Topsin M), or iprodione (Chipco 26019)	For Botrytis, Rhizoctonia, Sclerotinia, and Sclerotium stem and root rots **only**. Apply as a soil drench at 1 pint per square foot or work into upper 2 to 4 inches of soil before planting. Check labels for crop registrations.
	etridiazole (Truban or Terrazole), Banrot, metalaxyl (Subdue), PCNB-etridiazole (SA Terraclor Super-X), propamocarb (Banol), or fosetyl-Al (Aliette)	For Aphanomyces, Phytophthora, and Pythium stem and root rots (water molds) **only**. Usually applied as a soil drench at intervals of 2 to 8 weeks. Check label instructions. Sometimes combined with PCNB (Terraclor) or other fungicide.
Leaf, stem, and flower spots or blights caused by fungi Botrytis blight or gray-mold	benomyl + captan, maneb, mancozeb, chlorothalonil (Daconil 2787, Exotherm Termil), vinclozolin (Ornalin), iprodione (Chipco 26019), thiophanate-methyl + maneb and zinc ion (Duosan, Zyban), triadimefon (Bayleton), or triforine (Funginex)	Benomyl plus captan, chlorothalonil, maneb, or mancozeb also gives *Botrytis* control, as does vinclozolin, iprodione, and thiophanate-methyl plus maneb and zinc ion. Applications are needed at intervals of 5 to 7 days in rainy weather and every 7 to 10 days in drier weather. Check labels for specific information and crop registrations.
Rusts	maneb, mancozeb, oxycarboxin (Plantvax), triadimefon (Bayleton), triforine (Funginex), or Rubigan A.S.	Applications are usually needed at intervals of 7 to 10 days starting when rust first appears. Check labels for current crop registrations.

Disease	Chemicals for control	Remarks
Powdery mildews	benomyl, sulfur, dinocap (Karathane), triforine (Funginex), triadimefon (Bayleton), thiophanate-methyl (Topsin M), Zyban, Duosan, or Rubigan A.S.	Frequent applications and thorough coverage are essential. Sulfur, and dinocap may cause plant injury, especially in hot weather at 85°F or above. Check labels for current crop registrations.
Bacterial flower, leaf, and shoot blights	streptomycin formulations or copper fungicide	Strictly follow manufacturer's directions or plant injury may result. Note label restrictions.
Wilt diseases (mostly *Fusarium* and *Verticillium*) Crown and root rots Fasciation Crown gall	Steam at 180°F for 30 minutes or 160°F for 1 hour at the coolest spot or fumigate soil with methyl bromide, Vorlex, Vorlex 201, chloropicrin, or Vapam Soil Fumigant. Methyl bromide-chloropicrin or chloropicrin provide the best control of Verticillium wilt.	Treat soil several days to a month before planting. Carefully follow the manufacturer's directions as chemicals are very toxic and some can be used only by licensed commercial applicators. Also treat containers, benches, work surfaces, potting table, tools, and other equipment. Galltrol-A and Norbac 84-C are crown gall controls.
Soil nematodes (including root-knot and root-lesion nematodes)	Same as for wilt diseases above or apply Dasanit, Mocap, Nemacur, Temik, or Vydate 2L.	For application by certified commercial applicators only. Carefully follow all label directions and precautions. See labels for specific uses.
Foliar nematodes	Same as for wilt diseases above or use oxamyl (Vydate 2L) or aldicarb Temik 10G).	For application by certified commercial applicators only. Carefully follow all label directions and precautions. See label for Vydate 2L and Temik 10G uses.
Viruses Viroids Mycoplasmas	Apply insecticides at frequent intervals to keep the insects from feeding, as recommended by University of Illinois Extension entomologists.	Control insects that transmit the causal agents, especially leafhoppers, aphids, and thrips. Destroy the first infected plants. Keep down all broadleaf weeds.

Table 3. Instructions for Specific Flowers and Other Nonwoody Ornamentals

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
AFRICAN VIOLET				
Botrytis blight	chlorothalonil	See label	See label	Spray at 1- to 2-week intervals during cool, damp, overcast weather. In greenhouses, may use Exotherm Termil.
	benomyl, 50% WP	1/2 lb	2 t	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Topsin M	See label	See label	
	mancozeb	See label	See label	
Nematodes: foliar	Temik, 10G	See label	See label	Apply 18-28 oz/1,000 sq ft of bed.
Nematodes: soil	Temik, 10G	See label	See label	Apply 28-37 oz/1,000 sq ft of bed.
Nematodes: root-knot, sting, lesion, stunt	Vydate 2L	15-20 gal	See label	Preplant incorporate 4 to 8 inches.
	Potted soil mix	27-1/2 fl oz	See label	Spray 2.5 to 3.3 gal/1 cu yd of soil while tumbling in mixer.
	Pot drench	1 pint	See label	4 to 8 oz/6-inch pot, 2 to 4 oz/4-inch pot. Apply as a dilute spray not to exceed 8 pints per acre. Apply when plant is actively growing and not under stress. Use a spreader-sticker.
	Foliar	2-4 pints	See label	
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Apply at 10- to 14-day intervals; more frequently when disease is severe. Add a spreader-sticker to the spray. Do not apply Karathane to open flowers. Milban is a restricted-use pesticide.
	Karathane, 19.5% WP	1/4 lb	1 t	
	Milban, 39% EC	See label	See label	
	Bayleton, 25% WP	2-4 oz	See label	
	Rubigan A.S., 11% L	See label	See label	
Crown and stem rots	Banol, Truban, Terrazole, or Subdue + PCNB (Terraclor), 75% WP	See labels	See labels	Drench established plants once. You can purchase the fungicides separately or as a combination mix. Or blend granules into soil mix just before planting. Repeat at 4- to 12-week intervals as needed. Avoid overwatering.
	Banrot	See label	See label	
AGERATUM				
Cercospora leaf spot Powdery mildew Rust	Bayleton 25% WP	2-4 oz	See label	Spray at bud break and repeat 30 days later or when disease first appears.
Damping off Crown and root rots	etridiazole (Truban or Terrazole)	See labels	See labels	Apply as soil drench or mix into potting soil before planting.

[a] WP = wettable powder; L = liquid; EC = emulsifiable concentrate; G = granular.
[b]T = tablespoon(s); t = teaspoon(s); lb = pound(s); oz = ounce(s).
[c]sq ft = square foot (feet); gal = gallon(s); qt = quart(s).

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
AJUGA				
Sclerotium (crown) rot or southern blight	PCNB (Terraclor),	See label	See label	Apply PCNB as dust or granules on soil surface before planting. Thoroughly work into top 2 inches of soil. See label for Banrot applications.
	Banrot	See label	See label	
Powdery Mildew	Rubigan A.S., 11% L	3 to 5 fl oz	See label	Make two applications 10 to 14 days apart.
Nematodes (nursery stock)	Nemacur, 10G	See label	See label	Apply 180 lb per acre postplant and irrigate with 1/2 inch of water. One application per year.
	Temik, 10G (SLN 8000-003)	92-122 oz/ 1,000/sq ft	See label	Sidedress 3-4 inches deep, 10-12 inches, on each side of row.
AMARYLLIS				
Red blotch or leaf scorch	copper oxychloride	See label	See label	Keep the foliage protected during wet periods. To ensure coverage, add a spreader-sticker to the spray mix.
ASTER, CHINA				
Botrytis blight (bud and stem rot and petal blight)	benomyl, 50% WP	1/2 lb	2 t	For Botrytis petal blight, spray weekly starting when buds form. For mildew, start spraying when disease first appears. Apply benomyl sprays to seedlings at 2-week intervals to control Botrytis stem rot. Only benomyl and Topsin M control powdery mildew.
	chlorothalonil	See label	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
Powdery mildew	Topsin M	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Karathane, 19.5% WP	1/4 to 1/2	2t	
	Rubigan A.S., 11% L	See label	See label	
Rust	mancozeb	See label	See label	Spray at 7- to 21-day intervals. See label. Begin when disease first appears. Add a spreader-sticker (surfactant) to the spray mix.
Fungal leaf spots	Bayleton, 25% WP	2-4 oz	See label	
	triforine (Funginex)	See label	1-1/2 T	
	Ziram	See label	See label	
Rhizoctonia stem (crown) and root rot	PCNB (Terraclor), 75% WP	1/2 lb	1/2 T	Thoroughly drench soil once using 1 pint to 1 qt per sq ft. Spray the base of seedlings with benomyl 50% WP at 1 t per gal of water. Apply Chipco 26019 at transplant time.
	Banrot	See label	See label	
	Chipco 26019, 50% WP	6-1/2 oz	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
ASTER, CHINA, cont.				
Sclerotinia or cottony stem rot	benomyl, 50% WP	1/2 lb	2 t	Spray the stems and soil surface at 2- to 4-week intervals during cool, rainy, and overcast periods.
	Ornalin, 50% WP	1/2-1 lb	See label	
Root rots	Banrot	See label	See label	Drench seedlings and older plants at 2- to 4-week intervals using 1 pint to 1 qt per sq ft of bed with 40% WP or mix 8% granules into soil before planting.
Aster yellows	Apply recommended insecticide at frequent intervals.	See label	See label	Spray weekly, starting about mid-June. Six-spotted leaf-hoppers are vectors of the aster yellows mycoplasma. Or grow plants under 22-thread cloth to keep out insects.
Foliar nematodes	Temik, 10G	See label	See label	See African Violet.
AZALEA—See *1990 Plant Disease Control Guide: Woody Ornamentals*, Circular 1260.				
BEGONIA				
Botrytis blight, leaf spot, and stem rot	benomyl, 50% WP	1/2 lb	2 t	Spray at least weekly during cool, damp, overcast weather. In greenhouses, may use Exotherm Termil according to label directions. Check label registrations.
	Ornalin, 50% WP	1/2-1 lb	See label	
	chlorothalonil	See label	See label	
Other fungal leaf spots	Zyban, 75% WP	1-1/2 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Topsin M	See label	See label	
	mancozeb	See label	See label	
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Spray at 7- to 14-day intervals, starting when mildew first appears. Add a spreader-sticker to the spray mix. Milban is a restricted-use pesticide.
	Karathane, 19.5% WP	1/4 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
	Milban, 39% EC	See label	See label	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
Nematodes (Reiger begonia)	Vydate 2L	See label	See label	See African Violet.
	Temik 10G	See label	See label	
Root and stem or crown rots	PCNB (Terraclor), 75% WP + Truban, Terrazole, or Subdue	See labels	See labels	Apply monthly drenches to plants and soil. Do not apply to very young seedlings or blend granules into soil mix just before planting. Follow manufacturer's directions.
	Banrot	See label	See label	
Damping-off Tuber rot	captan, 50% WP	4 lb	8 T	Soak clean, disease-free begonia tubers for 30 minutes. Drain and plant in well-drained soil.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
BEGONIA, cont.				
Bacterial leaf spot	Kocide 606, 37.5%	2 pt	2 t	Keep foliage protected. Avoid wetting the foliage when watering.
CALENDULA				
Fungal leaf spots	benomyl, 50% WP	1/2 lb	2 t	Spray or dust foliage and flowers at 7- to 14-day intervals. Start when disease first appears.
	Topsin M	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Several spray or dust applications are usually needed, 7 to 10 days apart. Start when mildew first appears. Check label instructions and precautions.
	Karathane, 19.5% WP	1/4 lb	1 t	
	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4 T	
	triforine (Funginex)	See label	See label	
	Topsin M	See label	See label	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
	Bayleton, 25% WP	2-4 oz	See label	
Rhizoctonia stem and root rot	PCNB (Terraclor), 75% WP	1 lb	1 T	Apply Terraclor as a soil drench once or work dust or granules into the top 2 inches of soil about a week before planting. Apply benomyl and Banrot 40% WP as drenches to plants and soil or mix 8% Banrot granules into soil before planting.
Sclerotinia (cottony) stem and root rot	benomyl, 50% WP	See label	See label	
	Banrot	See label	See label	
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
CALLA				
Bacterial soft rot	formaldehyde, 38-40% L	See label	See label	Before planting, soak disease-free, dormant rhizomes for 1 hour in solution of 1 part of formaldehyde in 49 parts of water.
CARNATION				
Alternaria branch rot and leaf spot	maneb	See label	See label	Use mancozeb, maneb, or Ziram and captan in alternate sprays at 7- to 10-day intervals. Apply at first sign of disease. Add a spreader-sticker to spray to ensure wetting the foliage. Sanitary measures are important. Spray Zyban, Duosan, Dyrene, and chlorothalonil according to label directions.
	mancozeb	See label	See label	
	captan, 50% WP	2 lb	2 T	
Greasy blotch	Duosan, 75% WP	1-1/2 lb	See label	
Other fungal leaf spots	Zyban, 75% WP	1-1/2 lb	See label	
	chlorothalonil	See label	See label	
Anthracnose	Dyrene, 50% WP	1 lb	See label	
	Ziram	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
CARNATION, cont.				
Rust	mancozeb	See label	See label	Spray at 7- to 10-day intervals and include a spreader-sticker. Start with captan when cuttings are first stuck in the propagating bench. Keep water off the foliage
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	captan, 50% WP	2-1/2 lb	2-3 T	
	Bayleton, 25% WP	2-4 oz	See label	
	triforine (Funginex)	See label	See label	
	Ziram	See label	See label	
Botrytis blight or gray-mold	captan, 50% WP	1/2 lb	1 T	Apply at 7- to 10-day intervals in damp, cloudy weather. Start when disease first appears. During bloom, apply twice weekly. In greenhouses, may use Exotherm Termil. Ornalin may also be used as a postharvest spray to cut flowers.
	benomyl, 50% WP	1/2 lb	2 t	
	chlorothalonil	See label	See label	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Topsin M	See label	See label	
	maneb, 80% WP	See label	See label	
Rhizoctonia stem rot	PCNB (Terraclor), 75% WP	1 lb	1 T	Apply Terraclor or Banrot once as preplant drench. Follow the manufacturer's directions. Spray base of cuttings after they are stuck or spray transplants with benomyl or Chipco 26019.
	benomyl, 50% WP	1 lb	4 t	
	Banrot	See label	See label	
	Chipco 26019, 50% WP	6-1/2 oz	See label	
Fusarium stem rot	captan, 50% WP	1-1/2 lb	1/2 T	Apply captan on a weekly basis. Spray cuttings in rooting medium with benomyl.
	benomyl, 50% WP	1/2 lb	2 t	
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Begin when disease first appears. Repeat at 5- to 21-day intervals. Check label.
	Bayleton, 25% WP	2-4 oz	See label	
	sulfur, 80-95%	3-5 lb	2-1/2 to 4 T	
	Rubigan A.S., 11% L	See label	See label	
Pythium root rot	Banrot	See label	See label	Apply as soil drenches at 3- to 8-week intervals using 1 gal per 8 sq ft of bed. Water chemical in well, or mix with greenhouse soil before planting.
Phytophthora root rot Damping-off	Truban, Terrazole, Banol, or Subdue	See labels	See labels	
CHRYSANTHEMUM (See also Pot Mums and Field Mums.)				
Ascochyta stem and ray blight	maneb	See label	See label	Spray foliage and flowers at 5- to 10-day intervals during damp weather. Start when disease first appears. Add a commercial spreader-sticker (surfactant) to the spray to ensure wetting the foliage. Mix benomyl with another fungicide. Follow label directions and and check label registrations.
	mancozeb	See label	See label	
Septoria and other fungal leaf spots	captan, 50% WP	2 lb	2 T	
	chlorothalonil	See label	See label	
	benomyl, 50% WP	1 lb	1 T	
Anthracnose	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Ziram	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
CHRYSANTHEMUM, cont.				
Rust	Rubigan A.S., 11% L	3-5 fl oz	See label	Spray at 7- to 10-day intervals, starting a week before rust is expected.
	mancozeb	See label	See label	
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	Bayleton, 25% WP	2-4 oz	See label	
Botrytis flower blight or gray-mold	maneb	See label	See label	Spray foliage or mist-spray blooms weekly during cool, damp, overcast periods. Use fungicides at half-strength on blooms. In greenhouses, may use Exotherm Termil. Ornalin also may be used as a postharvest spray.
	benomyl, 50% WP	1/2 lb	2 t	
	Ornalin, 50% WP	1/2-1 lb	See label	
	chlorothalonil	See label	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Topsin M	See label	See label	
	Botran, 75% WP	1/2 - 3/4 lb	1/2 - 3/4 T	
	mancozeb	See label	See label	
Powdery mildew	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4 T	Spray at 7- to 14-day intervals, starting when mildew first appears. Add a commercial spreader-sticker (surfactant) to the spray mix. Milban is a restricted-use pesticide.
	benomyl, 50% WP	1/2 lb	2 t	
	Karathane, 19.5% WP	1/4-1/2 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
	Milban, 39% EC	See label	See label	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
Foliar nematodes	Temik, 10G	See label	See label	See African Violet.
	Systox 2	See label	2-4 pints	Spray plants until thoroughly wet.
	soil drench	See label	2-4 pints	Apply 1/4 pint per sq ft of bed or bench. For potted plants use 1/4 pint per 6-inch pot. Follow label directions.
Nematodes	Dasanit, 15G	Granules	See label	Apply evenly and incorporate 4 to 6 inches into soil.
	pot mix	Granules	See label	Mix thoroughly into soil. Outdoor use only.
	Temik, 10G	See label	See label	See African Violet.
	Vydate 2L	See label	See label	See African Violet.
Pot Mums Root and stem or foot rots	Subdue, Truban, Terrazole, or Banol +	See labels	See labels	Make one soil drench application at 100 gal per 400 sq ft of bed. Or mix Banrot or Terraclor into top 2 inches of soil before planting. Mist-spray base of plants with Subdue, Truban, Terrazole, or Banol plus benomyl at 1 t of each per gal of water.
	PCNB (Terraclor)	See label	See label	
	Banrot	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
CHRYSANTHEMUM, cont.				
Field Mums				
Root and stem or foot rots	Subdue, Truban, Terrazole, or Banol +	See labels	See labels	Make one soil drench application at 100 gal per 400 sq ft of bed at seeding or transplanting. Or mix Banrot or Terraclor into top 2 inches of soil before planting. Mist-spray base of plants with Subdue, Terrazole, Truban, or Banol plus benomyl at 1 t of each per gal of water.
	PCNB (Terraclor)	See label	See label	
	Banrot	See label	See label	
Rhizoctonia stem rot	benomyl, 50% WP	1 lb	1 T	Spray the base of transplants thoroughly and repeat the application 10 to 14 days later.
Sclerotinia (cottony) stem rot	Ornalin, 50% WP	1/2-1 lb	See label	
	Chipco 26019, 50% WP	6-1/2 oz	See label	
Aster yellows Spotted wilt	Apply recommended insecticides at frequent intervals.			Spray at about weekly intervals. Six-spotted leafhoppers are vectors of the aster yellows mycoplasma. Thrips transmit the spotted wilt virus.
CINERARIA				
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Apply sprays at 7- to 10-day intervals during cool, damp, overcast weather. Sanitation is also very important.
	chlorothalonil	See label	See label	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Spray at 7- to 10-day intervals. Start when mildew is first seen. Karathane may damage open flowers.
	Karathane, 19.5% WP	1/4 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
	Rubigan A.S., 11% L	See label	See label	
Root and crown rots	Truban or Terrazole +	See labels	See labels	Drench the soil once with the fungicide mix. Use 1 pint per sq ft of bed or 1/2 pint per 6-inch pot.
	PCNB (Terraclor), 75% WP	1/4 lb	1 t	
CLEMATIS				
Ascochyta leaf spot and stem rot	benomyl, 50% WP	1/2 lb	2 t	Spray the foliage thoroughly at 7- to 10-day intervals during rainy spring and early summer weather.
	sulfur, 80-95% WP	3-4 lb	2-3 T	
Nematodes	Nemacur, 10G	See label	See label	See Ajuga.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
CYCLAMEN				
Botrytis blight or crown rot	benomyl, 50% WP	1/2 lb	2 t	Spray at 7- to 10-day intervals during damp, overcast weather. Mist-spray blooms at 3- to 7-day intervals with benomyl at 1/2 rate. In greenhouses, may use Exotherm Termil.
	Ornalin, 50% WP	1/2-1 lb		
	chlorothalonil	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Fungal leaf spots	Chipco 26019, 50% WP	1-2 lb	1-2 T	Spray the foliage at weekly intervals during wet weather.
Nematodes	Dasanit, 15G	See label	See label	See Chrysanthemum.
	Temik, 10G	See label	See label	See African Violet.
DAFFODIL—See Narcissus.				
DAHLIA				
Botrytis flower blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Mist-spray blooms weekly in cool, damp, overcast weather. Start when disease first appears. Add a commercial spreader-sticker (surfactant) to the spray to ensure wetting.
	maneb	See label	See label	
	mancozeb	See label	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Powdery mildew	triforine (Funginex)	See label	See label	Spray or dust the foliage at 7- to 10-day intervals, starting when mildew first appears. Avoid applications in hot weather at temperatures over 85°F. Apply Apply benomyl, Bayleton, or Funginex at 10- to 14-day intervals.
	benomyl, 50% WP	1/2 lb	2 t	
	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4	
	Karathane, 19.5% WP	1/4-1/2 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
	Rubigan A.S., 11% L	3 to 5 fl oz	See label	
Crown and root rots	Banrot	See label	See label	Drench seedlings and transplants with Banrot or Chipco 26019 or blend Banrot , Truban or Terrazole into soil before planting. Follow the manufacturer's directions.
	Chipco 26019, 50% WP plus	6-1/2 oz	See label	
	etridiazole (Truban, Terrazole)	See labels	See labels	
Foliar nematodes	Temik, 10G	See label	See label	See African Violet.
DELPHINIUM, LARKSPUR				
Sclerotium root and crown rot	PCNB (Terraclor), 75% WP	1 lb	1 T	Apply as a soil drench at 1 pint per sq ft after planting or to the base of established plants as new growth appears. Banrot or Terraclor granules can be blended into soil before planting.
Sclerotinia wilt	Banrot	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
DELPHINIUM, LARKSPUR, cont.				
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Spray the foliage thoroughly at 7- to 21-day intervals, starting when mildew is first seen. Follow all label directions carefully.
	Karathane, 19.5% WP	1/4 lb	1 t	
	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4 T	
	Bayleton, 25% WP	2-4 oz	See label	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
Fungal leaf spots	benomyl, 50% WP	1/2 lb	2 t	Spray at 7- to 10-day intervals. Start when disease first appears. Sanitary measures are important.
	Topsin M	See label	See label	
Botrytis blight or gray-mold	chlorothalonil	See label	See label	Spray the foliage and flowers at 7- to 10-day intervals during cool, damp, overcast periods. Reduce the fungicide rate when the plants are in flower.
	benomyl, 50% WP	1/2 lb	2 t	
	Topsin M	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Ornalin, 50% WP	1/2-1 lb	See label	
Black leaf spot	fixed copper, 50-56% Cu	See label	See label	Drench soil at base of plants in fall. Spray young shoots in spring with fixed copper at 2 T per gal of water.
DIEFFENBACHIA				
Bacterial soft rot or stem rot	streptomycin formulations	Apply at 200 parts per million.	See label	Dip cane cuttings. Carefully follow the manufacturer's directions on the label.
Fungal root and stem rots Damping-off	Banrot	See label	See label	Keep soil mix on the dry side. Apply Banrot as a soil drench or blend granules into soil before planting. Follow label directions.
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Spray the foliage at 10-day intervals in cool, damp weather. Sanitary measures are important.
	Ornalin, 50% WP	1/2-1 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	mancozeb, 80% WP	1-1/2	1-1/2	
Bacterial leaf spot	streptomycin formulations	Apply at 200 parts per million.	See label	Spray the foliage and canes during damp weather, starting when disease appears. Follow all label directions carefully.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
DIEFFENBACHIA, cont.				
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
FOLIAGE PLANT				
Botrytis blight or gray-mold Sclerotinia blight	mancozeb, 80% WP	1-1/2	1-1/2	Spray the foliage at 10-day intervals in cool, damp weather. Sanitary measures are very important.
	benomyl, 50% WP	1/2 lb	2 t	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	chlorothalonil	See label	See label	
Fungal cutting, stem, or root rots	Banrot	See label	See label	Apply 100 gal to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Retreat at 4 to 12-week intervals. Apply once as a soil drench at 1 pint per sq ft to established plants. Water liberally. Or blend granules into potting soil before planting. Follow label directions.
	Truban, Terrazole, Subdue +	See labels	See labels	
	PCNB (Terraclor), 75% WP	1/4 lb	1 t	
Nematodes	Mocap EC	See label	See label	See Gardenia.
Fungal leaf spots	benomyl, 50% WP	1/2 lb	2 t	Keep water off the foliage. Spray at 10-day intervals during rainy periods. Start when disease appears. Add a commercial spreader-sticker (surfactant) to the spray mix.
	mancozeb	See label	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Kocide 606, 37.5% L	2 pt	2t	
	chlorothalonil	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Root rots	Banrot			Apply 100 gal of 40% WP to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediaely. Retreat at 4- to 12-week intervals.
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
	Nemacur, 10G	See label	See label	See Ajuga.
FREESIA				
Bacterial scab	thiram, 75% WP	See label		Thoroughly dust corms before planting and again after cleaning and before putting in storage for the winter.
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Spray foliage and flowers at 7- to 10-day intervals in cool, damp, overcast weather. Follow label directions.
	Ornalin, 50% WP	1/2-1 lb	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
FUCHSIA				
Botrytis blight or gray-mold	chlorothalonil	See label	See label	Spray at 7- to 10-day intervals in cool, damp, overcast weather. In greenhouses, may use Exotherm Termil. Chlorothalonil and mancozeb also control rust.
Rust	benomyl, 50% WP	1/2 lb	2 t	
	Ornalin, 50% WP	1/2-1 lb	See label	
	mancozeb	See label	See label	
Nematodes	Vydate 2L	See label	See label	See African Violet.
GARDENIA				
Fungal leaf spots	maneb, 80% WP	1-1/2 lb	1-1/2 T	Spray cuttings and plants at 7- to 10-day intervals. Start when disease first appears. Add a commercial spreader-sticker (surfactant) to the spray.
	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	
	chlorothalonil	See label	See label	
	fixed copper, 50-56% Cu	See label	See label	
Crown and root rots	Banrot	See label	See label	Apply 100 gal of 40% WP Banrot to 400 sq ft of bed or 1/2 pint per 6-inch pot. Irrigate immediately. Or apply 8% Banrot granules and blend into soil before planting.
Nematodes	Dasanit, 15G	See label	See label	See Chrysanthemum.
	Mocap EC			Apply 1 gal per sq yd. Wash from foliage. After treatment, wet soil to 6 to 12 inches.
	Field nursery stock	1/2 pint	See label	
	Bed and bench	1/2-1 pint	See label	Mix with enough water to cover 1,000 sq ft. Wet soil to 4 to 6 inches.
	Pot drench	1/2 pint	See label	Drench with 1/2 pint per 6-inch pot and 1 pint per 8-inch pot.
	Root dip	1 pint	See label	Allow only roots to soak for 30 minutes.
	Nemacur, 10G	See label	See label	See Ajuga.
	Temik, 15G	See label	See label	See African Violet.
	Vydate 2L	See label	See label	See African Violet.
GERANIUM (*Pelargonium*)				
Botrytis blight or gray-mold	mancozeb, 80% WP	1-1/2	1-1/2	Spray weekly during cool, rainy or damp, overcast weather. Start a month before first cuttings are taken. In greenhouses, may use Exotherm Termil. Keep old flowers and leaves picked off and keep water off the foliage. Check label registrations.
	benomyl, 50% WP	1/2 lb	2 t	
	Ornalin, 50% WP	1/2-1 lb	See label	
	chlorothalonil	See label	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Topsin M	See label	See label	
	Botran, 75% WP	1/2-3/4 lb	1/2-3/4 T	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
GERANIUM, cont.				
Fungal leaf spots	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	Spray or dust at 7- to 14-day intervals. Start when disease first appears. Keep the foliage protected during damp, overcast weather when infections occur. Sanitary measures are important.
	chlorothalonil	See label	See label	
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Topsin M	See label	See label	
	benomyl, 50% WP	1/2 lb	2 t	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Rust	Plantvax, 75% WP	1 to 1-1/2 lb	1 T	Apply Plantvax or Bayleton at 2- to 4-week intervals when rust first appears. Spray maneb, mancozeb, and chlorothalonil at 7- to 10-day intervals, starting when rust is first evident.
	mancozeb	See label	See label	
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	Bayleton, 25% WP	2-4 oz	See label	
	chlorothalonil	See label	See label	
Rhizoctonia root and stem rot Damping-off	PCNB (Terraclor), 75% WP	1/2 lb	2 t	Drench established plants with Terraclor or Banrot once, using 1 pint to 1 qt per sq ft or 1/2 pint per 6-inch pot. Spray base of plants with benomyl every 2 to 3 weeks. Apply Chipco 26019 at seeding and transplant time.
	benomyl, 50% WP	1/2 lb	2 t	
	Banrot	See label	See label	
	Chipco 26019, 50% WP	6-1/2 oz	See label	
Blackleg (*Pythium*)	Subdue, Truban, Banol, or Terrazole	See labels	See labels	Spray cuttings in the cutting bench. Several spray applications may be needed, spaced 1 to 3 weeks apart. Or blend granules into soil mix just before planting.
Other root rots	Subdue, Terrazole or Truban +	See labels	See labels	Drench established, well-rooted plants once. Use 1-1/2 pints to 1 qt of fungicide mix per sq ft or 1/2 pint per 6-inch pot.
	benomyl, 50% WP	1/2 lb	2 t	
	Banrot	See label	See label	
Foliar nematodes	Temik, 15G	See label	See label	See African Violet.
GERBERA, TRANSVAAL DAISY				
Phytophthora root rot	Truban or Terrazole	See labels	See labels	Apply as a soil drench or mix granules thoroughly into the soil just before planting. Follow manufacturer's directions.
	captan, 50% WP	2 lb	2 T	
	Banrot	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
GERBERA, TRANSVAAL DAISY, cont.				
Powdery mildew	Rubigan A.S., 11% L	See label	See label	Apply several sprays at 7- to 14-day intervals, starting when mildew first appears
	benomyl, 50% WP	1/2 lb	2 t	
	Karathane, 19.5% WP	1/4 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
Botrytis blight Damping-off Sclerotinia blight	Ornalin, 50% WP	1/2-1 lb	See label	Spray foliage at 7- to 10-day intervals in damp, cloudy weather. Drench soil at seeding time.
	benomyl, 50% WP	1/2 lb	2 t	
Nematodes	Vydate 2L	See label	See label	See African Violet.
GLADIOLUS				
Fusarium yellows and corm rot Penicillium corm rot	benomyl, 50% WP	1-2/3 lb	2 T	Within 24 hours after digging, soak corms in a basket or loosely woven sack for 15 to 30 minutes at a water temperature of 80° to 85°F. Or dust corms as for bacterial scab. Dry and store properly.
	Mertect 340-F, 42.28% L	30 fl oz	See label	
	Ornalin, 50% WP	1-1/2 to 2 lb	See label	
	Topsin M	See label	See label	
	Cleary 3336	See label	See label	
	Busan, 75% EC	1 pt	See label	
Stromatinia corm rot	Botran, 75% WP	20 lb	20 T	Before planting, dip corms following label directions. Or apply Botran in-furrow at 1-1/3 lb per 1,000 ft of row at planting time.
	Ornalin, 50% WP	1-1/2 to 2 lb	See label	
	PCNB (Terraclor)	See label	See label	
Bacterial scab	thiram, 75% WP	See label	See label	Dust disease-free corms with thiram or thiram-insecticide combination before planting and just before storage.
Nematodes	Dasanit, 15G	See label	See label	See Chrysanthemum.
	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	92-122 oz/1,000 ft of row. Apply in-furrow or band incorporate at least 4 inches deep at planting time.
Botrytis leaf and flower spot and corm rot	Topsin M	See label	See label	Spray weekly during damp or rainy periods. Start when disease first appears. Spray the cut flower spikes with benomyl before shipment or storage. Treat the corms as for Fusarium yellows. Check label registrations. Ornalin may also be used as a postharvest cut flower or corm dip.
	benomyl, 50% WP	1/2 lb	2 t	
	mancozeb	See label	See label	
	captan, 50% WP	2 lb	2 T	
	chlorothalonil	See label	See label	
	maneb	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Botran, 75% WP	3/4 lb	3/4 T	
	maneb, 80% WP	3/4 lb	3/4 T	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
GLADIOLUS, cont.				
Other fungal leaf spots	mancozeb	See label	See label	Spray weekly during rainy periods, starting when the leaf spots first appear. Add a commercial spreader-sticker (surfactant) to the spray.
	maneb	See label	See label	
	Dyrene, 65% WP	2 lb	2 T	
	chlorothalonil	See label	See label	
	Ziram	See label	See label	
GLOXINIA				
Botrytis bud and flower rot	benomyl, 50% WP	1/2 lb	2 t	Spray weekly in cool, damp, overcast weather. Start when the buds first begin to appear. Sanitary measures are important.
	chlorothalonil	See label	See label	
	Topsin M	See label	See label	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
Crown rot Leaf and tuber rot	Banrot	See label	See label	Drench established plants once, using 1 pint to 1 qt per sq ft of bed or 1/2 pint per 6-inch pot. Or blend granules into soil mix just before planting.
	Banol, Subdue, Truban, or Terrazole	See labels	See labels	
HOLLYHOCK				
Rust Leaf spots Anthracnose	chlorothalonil	See label	See label	Thoroughly spray or dust 5 or 6 times, 7 to 10 days apart. Start when new foliar growth commences in the spring. Sanitation is important. Check label registrations.
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	mancozeb	See label	See label	
	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4 T	
	Bayleton, 25% WP	2-4 oz	See label	
HYACINTH				
Botrytis blight or gray-mold	PCNB (Terraclor), 75% WP	1/2 lb	1 T	Drench once after panning. Repeat if gray-mold appears, using Botran at half-strength. Or try benomyl 50% WP at 1/2 lb per 100 gal or 2 t per gal. Check label registrations. Apply Ornalin as a spray only.
	Botran, 75% WP	1 lb	1 T	
	Ornalin, 50% WP	1/2-1 lb	See label	
Fungal bulb rots	Truban or Terrazole +	See labels	See labels	See remarks for root rot complex of lily for fungicide combinations. Dust disease-free bulbs with thiram just before planting or storage or dip bulbs for 5 to 30 minutes in an Ornalin, PCNB (Terraclor) 75% WP or Mertect 340-F suspension.
	benomyl, 50% WP	1/2 lb	2 t	
	or Mertect 340-F, 42.28% L	30 fl oz	See label	
	thiram, 75%WP			
	Ornalin, 50% WP	1-1/2 to 2 lb	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
HYDRANGEA—See *1990 Plant Disease Control Guide: Woody Ornamentals*, Circular 1260.				
IRIS				
Leaf spots Rust Botrytis blossom blight	chlorothalonil maneb, 80% WP mancozeb benomyl, 50% WP Bayleton, 25% WP Chipco 26019, 50% WP Topsin M	See label 1-1/2 lb See label 1 lb 1 lb 1-2 lb See label	See label 1-1/2 T See label 1 T See label 1-2 T See label	Spray 4 to 6 times, 7 to 10 days apart. Start when new leaves are several inches tall. Add a spreader-sticker to the spray to ensure better wetting and coverage. If rust is a problem, spray with mancozeb, maneb, Bayleton, or chlorothalonil.
Fungal crown, rhizome, and bulb rots	PCNB (Terraclor), 75% WP Botran, 50-75% WP Mertect 340-F, 42.28% L Topsin M Ornalin, 50% WP benomyl	1/2 lb 1-1/2 lb 30 fl oz See label See label See label	1 T 1-1/2 T See label See label See label See label	Apply as a soil drench at 1 pint to 1 qt per sq ft at or before planting and again when new growth appears in spring. Apply Mertect, Ornalin, benomyl, and Topsin M as bulb dips only. See under Gladiolus and Narcissus.
Bacterial soft rot and rhizome rot	Apply recommended insecticides starting when fan leaves are several inches tall.	See label	See label	Spray weekly until bloom. Dig up infected plants after flowering is over and transplant disease-free, borer-free rhizomes. The soft rot bacteria enter through fresh iris borer wounds and other injuries.
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Dasanit, 15G	See label	See label	See Chrysanthemum.
	Temik, 10G	See label	See label	See Gladiolus.
	Nemacur, 10G	See label	See label	See Ajuga.
IVY, ENGLISH				
Fungus leaf spots and blight Stem spot Twig blight	benomyl, 50% WP fixed copper, 50-56% Cu Duosan, 75% WP Zyban, 75% WP mancozeb, 80% WP Chipco 26019, 50% WP	1/2 lb See label 1-1/2 lb 1-1/2 lb 1-1/2 lb 1-2 lb	2 t See label See label See label 1-1/2 T 1-2T	Spray or dust several times at 7- to 10-day intervals. Keep the foliage protected during rainy spring and early summer weather. Start when the disease first appears.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
IVY, ENGLISH, cont.				
Root rot Crown rot	Banrot Chipco 26019, 50% WP	See label 6-1/2 oz	See label See label	Keep soil mix on the dry side. Apply Banrot as a soil drench or blend granules into soil before planting. Follow label directions. Apply Chipco 26019 at transplant time.
Nematodes	Nemacur, 10G Vydate 2L Temik, 10G	See label See label See label	See label See label See label	See Ajuga. See African Violet. See African Violet.
Botrytis blight or gray-mold	benomyl, 50% WP Ornalin, 50% WP Chipco 26019, 50% WP	1/2 lb 1/2-1 lb 1-2 lb	2 t See label 1-2 T	Spray the foliage at 10-day intervals in cool, damp weather. Sanitary measures are important.
KALANCHOE				
Crown or stem rot Wilt Root rot	Banrot	See label	See label	Drench plants once at 1 pint to 1 qt per sq ft or 1/2 pint per 6-inch pot. Or blend 8% Banrot granules into soil before planting.
Powdery mildew	benomyl, 50% WP Karathane, 19.5% WP Zyban, 75% WP Duosan, 75% WP Milban, 39% EC Rubigan A.S., 11% L	1/2 lb 1/4 lb 1-1/2 lb 1-1/2 lb See label See label	2 t 1 t See label See label See label See label	Spray at 7- to 14-day intervals. Start when mildew first appears. Add a commercial spreader-sticker (surfactant) to the spray. Milban is a restricted-use pesticide.
Botrytis blight or gray-mold Sclerotinia blight	benomyl, 50% WP Ornalin, 50% WP Duosan, 75% WP Zyban, 75% WP Chipco 26019, 50% WP	1/2 lb 1/2-1 lb 1-1/2 lb 1-1/2 lb 1-2 lb	2 t See label See label See label 1-2 T	Spray several times at 10-day intervals during cool, damp, overcast weather. Sanitary measures are very important. Keep water off the foliage.
Fungal leaf spots	Duosan, 75% WP Zyban, 75% WP	1-1/2 lb 1-1/2 lb	See label See label	Same as for Botrytis blight above. Keep water off the foliage.
Nematodes	Vydate 2L Temik, 10G	See label See label	See label See label	See African Violet. See African Violet.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
LARKSPUR—See Delphinium.				
LILY				
Root rot complex	Subdue, Terrazole, or Truban +	See labels	See labels	Drench established plants with Subdue, Terrazole, or Truban plus benomyl at 1/2 pint per 6-inch pot and repeat at monthly intervals. Or mix Subdue, Truban, Terrazole, or Banrot granules into potting mix. Banrot can be applied at 4- to 12-week intervals.
	benomyl, 50% WP	1 lb	4 t	
	Banrot	See label	See label	
	Banol, Subdue, Terrazole, or Truban +	See labels	See labels	Dip bulbs 10 to 30 minutes just before planting and within 24 hours after digging. Or mix Truban, Banrot, or Terrazole into porous potting mix. Drench growing plants monthly with Terrazole, Subdue, Truban, Banol, or Banrot. Follow manufacturer's directions.
	benomyl, 50% WP	2.7 oz	See label	
	or Mertect, 340-F, 42.28% L	30 fl oz	See label	
	Banrot	See label	See label	
	Topsin M	See label	See label	
Botrytis flower blight or gray-mold and leaf spot or blight	benomyl, 50% WP	1/2 lb	2 t	Spray 3 times, 7 days apart, starting when disease first appears on the lower leaves. Mist-spray buds and blooms with benomyl at 1/4 lb per 100 gal or 1t per gal. In greenhouses, may use Exotherm Termil. Sanitation is important.
	chlorothalonil	See label	See label	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Topsin M	See label	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	mancozeb	See label	See label	
	maneb	See label	See label	
Bulb rots (*Rhizopus* and *Penicillium*)	thiram, 75% WP or thiram + benomyl, 50% WP	See labels	See labels	Clean bulbs thoroughly and dust blemish-free ones with thiram or thiram plus benomyl before placing in storage. Discard all diseased bulbs when first discovered.
Fusarium bulb rot Phytophthora shoot or foot rot	Truban or Banol + benomyl, 50% WP or Mertect 340-F, 42.28% L	See labels	See labels	Thoroughly mix fungicides into soil just before planting or drench the plants after potting as outlined for root rot complex. Dip bulbs for 10 to 30 minutes as given under root rot complex.
	Banrot	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	Rate[b] 1 gallon	Remarks[c]
LILY, cont.				
Virus diseases	Apply recommended insecticides to prevent insects from feeding.			Spray at about weekly intervals to control aphids that spread the viruses from plant to plant. Or fumigate greenhouses following label directions.
Nematodes (Easter lily)	Nemacur, 10G	See label	See label	See Ajuga.
	Temik, 15G	See label	See label	
	Dasanit, 15G	See label	See label	See Chrysanthemum.
MARIGOLD				
Botrytis blight or gray-mold	mancozeb	See label	See label	Apply several sprays at 7- to 14-day intervals during cool, damp, overcast weather when infection occurs Sanitary measures are very important
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	benomyl, 50% WP	1/2 lb	2 t	
	chlorothalonil	See label	See label	
	Ornalin, 50% WP	1/2-1 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
Phytophthora stem rot and wilt	Banol, Terrazole, Truban, or Subdue	See label	See label	Thoroughly mix the fungicide into the soil just before planting and/or transplanting or apply as a soil drench after planting.
	Banrot	See label	See label	
Nematodes	Vydate 2L	See labels	See labels	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
NARCISSUS, DAFFODIL				
Fungal bulb rots	PCNB (Terraclor), 75% WP	50 lb	1/2 lb	Dip cleaned bulbs for 5 to 30 minutes in a suspension of Terraclor, Mertect, Cleary 3336, Topsin M, or benomyl with water at 80° to 85°F. Apply Ornalin according to label directions. Or dust bulbs with thiram before planting and again before putting in storage. Keep bulbs dry.
	Mertect 340-F, 42.28% L	30 fl oz	See label	
	benomyl, 50% WP	1-2/3 lb	2 T	
	Ornalin, 50% WP	1-1/2 to 2 lb	See label	
	thiram, 75% WP	See label	See label	
	Topsin M	See label	See label	
	Cleary 3336	See label	See label	
Foliar nematodes	Temik 10G	See label	See label	See African violet.
ORCHIDS				
Black rot Root rot Damping off	Truban or Terrazole	See labels	See labels	Drench plants following label directions. Or blend granules into potting medium before planting.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	Rate[b] 1 gallon	Remarks[c]
ORCHIDS, cont.				
Botrytis flower spot or blight or gray-mold	chlorothalonil	See label	See label	In closed greenhouses, you may use Exotherm Termil. Test trial varieties for possible injury.
	Ornalin, 50% WP	1/2-1 lb	See label	
	mancozeb	See label	See label	
Nematodes	Vydate 2L	See label	See label	See African Violet.
Foliar nematodes	Temik, 10G	See label	See label	See African Violet.
PACHYSANDRA				
Volutella leaf and stem blight or canker	mancozeb	See label	See label	Make 5 spray applications at about 10- to 14-day intervals starting in the spring when new growth begins.
	maneb, 80% WP	1-1/2 lb	1-1/2 T	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	chlorothalonil	See label	See label	
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Nemacur, 10G	See label	See label	See Ajuga.
	Temik, 10G	See label	See label	See African Violet.
PANSY, VIOLET, VIOLA				
Anthracnose Scab Fungal leaf spot Botrytis blight or gray-mold	mancozeb	See label	See label	Spray weekly during damp or rainy periods. Start when disease first appears. Add a spreader-sticker (surfactant) to all sprays. Also make a fall application just before covering plants with mulch. Check labels carefully.
	maneb	See label	See label	
	benomyl, 50% WP	1/2 lb	2 t	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	chlorothalonil	See label	See label	
Rust	Bayleton, 25% WP	2-4 oz	See label	Spray when disease first appears.
Powdery mildew	sulfur, 80-95% WP	3-5 lb	2-1/4 to 4 T	Follow label directions.
Seed rot Seedling blights Damping-off	captan	See label	See label	Dust seeds thoroughly with captan just before planting. Screen off excess fungicide. Avoid overseeding and overwatering. Apply Banrot as a soil drench or blend 8% granules into soil before planting. Follow label directions.
	Banrot	See label	See label	
Nematodes	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
PELARGONIUM—See Geranium.				
PEONY				
Botrytis blight, leaf blotch, bud blast, shoot blight, and leaf spot	mancozeb benomyl, 50% WP Topsin M maneb	See label 1 lb See label See label	See label 1 T See label See label	Spray weekly during cool, damp, overcast weather. Start when new shoot growth is 2 to 4 inches tall and continue until flowers begin to open. Add a commercial spreader-sticker to the spray.
Phytophthora blight	mancozeb maneb	See label See label	See label See label	Spray foliage, bases of shoots, and nearby soil at 7- to 10-day intervals during rainy periods. Add spreader-sticker to each spray to ensure wetting the foliage.
Foliar nematodes	Temik, 10G	See label	See label	See African Violet.
Nematodes	Vydate 2L	See label	See label	See African Violet.
PERIWINKLE (*Vinca minor*)				
Phoma stem rot or canker	benomyl, 50% WP	1 lb	1 T	Thoroughly soak stems and soil once before disease appears in midspring.
Nematodes	Nemacur, 10G Vydate 2L	See label See label	See label See label	See Ajuga. See African Violet.
PETUNIA				
Botrytis blight or gray-mold, leaf blotch, and flower blight	maneb, 80% WP benomyl, 50% WP Ornalin, 50% WP Duosan, 75% WP Zyban, 75% WP chlorothalonil mancozeb, 80% WP	1-1/2 lb 1/2 lb 1/2-1 lb 1-1/2 lb 1-1/2 lb See label 1-1/2	1-1/2 T 2 t See label See label See label See label 1-1/2	Apply sprays at 10- to 14-day intervals during cool, damp, overcast weather. In greenhouses, may use Exotherm Termil.
Nematodes	Vydate 2L	See label	See label	See African Violet.
Fungal root and crown or foot rots (*Pythium* and *Rhizoctonia*)	Banrot Truban, Terrazole, Subdue, or Banol + PCNB (Terraclor)	See label See labels	See label See labels	Drench the soil surface using 1 pint to 1 qt per sq ft of bed after plants are set. Repeat several more times at 3- to 12-week intervals. Or blend granules into soil before planting.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
PHILODENDRON				
Bacterial leaf spot	streptomycin formulations	Apply at 200 parts per million.		Remove spotted and dead leaves. Spray foliage during damp weather at 4- to 5-day intervals starting when disease first appears. Follow label directions.
	Kocide 606, 37.5%	2 pt	2 t	
Fungal leaf spots	Duosan, 75% WP	1-1/2 lb	See label	Spray several times about 10 days apart. Start when spots are first evident. Keep water off the foliage.
	Zyban, 75% WP	1-1/2 lb	See label	
	chlorothalonil	See label	See label	
	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	
Damping-off Root and stem rots	Banrot	See label	See label	Drench plants following the manufacturer's directions or blend granules into soil mix before planting.
Nematodes	Mocap EC	See label	See label	See Gardenia.
	Vydate 2L	See label	See label	See African Violet.
	Temik, 10G	See label	See label	See African Violet.
PHLOX				
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Spray several times, about 10 days apart. Start when mildew is first seen on the lower leaves. Proper spacing of plants and plenty of sunlight are important.
	Bayleton, 25% WP	2-4 oz	See label	
	Karathane, 19.5% WP	1/4 lb	1 t	
	triforine (Funginex)	See label	See label	
	sulfur, 80-95% WP	3-1/2 to 5 lb	2-1/2 to 4 T	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
Fungal leaf spots Rust	benomyl, 50% WP	1/2 lb	2 t	Spray several times, 7 to 10 days apart. Start when disease first appears on the leaves. For rust use Bayleton.
	Bayleton, 25% WP	2-4 oz	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
Root rots	Banrot	See label	See label	Drench plants following the manufacturer's directions.
POINSETTIA				
	mancozeb	See label	See label	Spray several times at 7- to 14-day intervals during cool, damp, overcast weather. Do not spray Ornalin when plants are in color; some poinsettia cultivars may be sensitive to leaf spotting.
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	
Stem canker and leaf spot	Ornalin, 50% WP	1/2-1 lb	See label	
Scab	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	chlorothalonil	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
POINSETTIA, cont.				
Root and stem rot complex *(Rhizoctonia, Thielaviopsis, Pythium,* etc.)	Banrot	See label	See label	If disease appears after potting, drench established plants once. Apply 1/2 pint per 6-inch pot. If disease appears later, apply Subdue, Banol, Truban, or Terrazole plus benomyl at 1/4 lb per 100 gal using 1/2 pint per 6-inch pot at 21-day intervals. Or apply Banrot alone according to label directions. Apply Chipco 26019 at transplant time to control *Rhizoctonia.*
	Truban, Terrazole, Subdue, or Banol +	See labels	See labels	
	PCNB (Terraclor), 75% WP or	1/4 lb	1 t	
	benomyl, 50% WP	1/2-1 lb	3 t	
	Chipco 26019, 50% WP	6-1/2 oz	See label	
ROSE — See *1990 Plant Disease Control Guide: Woody Ornamentals,* Circular 1260.				
SNAPDRAGON				
Anthracnose Fungal leaf spots	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	Spray or dust at 7- to 10-day intervals during rainy periods. Start when disease first appears. Adding a spreader-sticker ensures better wetting. In closed greenhouses, may use Exotherm Termil. Sanitation is important.
	chlorothalonil	See label	See label	
	benomyl, 50% WP	1/2 lb	2 t	
	captan, 50% WP	2 lb	2 T	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Topsin M	See label	See label	
	Ziram	See label	See label	
Botrytis blight or gray-mold Phyllosticta leaf and stem blight	benomyl, 50% WP	1/2 lb	2 t	Spray at weekly intervals during cool, damp, overcast weather. In closed greenhouses, may use Exotherm Termil. When plants are in bloom, use only benomyl and at half-strength: 1/4 lb per 100 gal or 1 t per gal.
	chlorothalonil	See label	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Chipco 26019, 50% WP	1-2 lb	1-2 T	
	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	
Rust Downy mildew Other fungal leaf spots and blights	mancozeb	See label	See label	Spray at 5- to 10-day intervals in damp or rainy weather. Start when disease first appears. Use mancozeb, maneb, Funginex, or Bayleton to control rusts. Bayleton will not control any of the other diseases.
	maneb	See label	See label	
	Zyban, 75% WP	1-1/2 lb	See label	
	Duosan, 75% WP	1-1/2 lb	See label	
	Bayleton, 25% WP	2-4 oz	See label	
	triforine (Funginex)	See label	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
SNAPDRAGON, cont.				
Powdery mildew	benomyl, 50% WP	1/2 lb	2 t	Spray at 7- to 10-day intervals. Add a commercial spreader-sticker to the spray. Use benomyl at 1 t per gal on seedlings.
	Karathane, 19.5% WP	1/4 lb	1 t	
	Bayleton, 25% WP	2-4 oz	See label	
	triforine (Funginex)	See label	See label	
	Rubigan A.S., 11% L	See label	See label	
Rhizoctonia stem and root rot or wirestem	PCNB (Terraclor), 75% WP	1/2 lb	1 1/2 t	Apply as a soil drench once to established plants when disease is expected.
	Banrot	See label	See label	Follow all label directions.
Damping-off	Chipco 26019, 50% WP	6-1/2 oz	See label	Apply Chipco 26019 at seeding and transplanting time.
Nematodes	Vydate 2L	See label	See label	See African Violet.
Pythium and Phytophthora crown and root rots	Banol, Subdue, Truban, or Terrazole	See labels	See labels	Drench established plants using 1 pint to 1 qt per sq ft. Repeat in 4 to 8 weeks if needed. Or blend granules into soil before planting.
	Banrot	See label	See label	
STATICE				
Anthracnose	chlorothalonil	See label	See label	Spray as buds break open in spring.
Cercospora, Alternaria, and Botrytis leaf blights	mancozeb	See label	See label	
Pythium Crown and root rots	etridiazole (Truban, Terrazole)	See label	See label	Drench soil or apply 1/2 pint/6-inch pot and repeat 4-12 weeks later.
STOCK				
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Spray several times at 7- to 10-day intervals during cool, damp, overcast weather. Sanitation is important.
	Duosan, 75% WP	1-1/2 lb	See label	
Fungal leaf spots	Zyban, 75% WP	1-1/2 lb	See label	
Root and stem rots	PCNB (Terraclor), 75% WP	1/2 lb	2 t	Drench plants using 1 pint to 1 qt per sq ft after transplanting. Repeat if the disease appears.
SWEETPEA				
Powdery mildew	Karathane, 19.5% WP	1/4 lb	1 t	Spray several times at 7- to 21-day intervals. Start when mildew first appears on the leaves. Check label directions.
	benomyl, 50% WP	1/2 lb	2 t	
	sulfur, 80-95% WP	3-5 lb	2-1/2 to 4 T	
	Rubigan, A.S., 11% L	3-5 fl oz	See label	
	Bayleton, 25% WP	2-4 oz	See label	

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	1 gallon	Remarks[c]
SWEETPEA, cont.				
Anthracnose Fungal leaf spots and blights	benomyl, 50% WP	1/2 lb	2 t	Spray several times at 10- to 14-day intervals during rainy weather. Start when disease is first evident.
Anthracnose Streak	formaldehyde, 38-40% L			Dip seed in formaldehyde solution for 5 minutes just before planting in fertile, well-drained soil.
Root and stem rots	PCNB (Terraclor) benomyl, 50% WP	See label See label	See label See label	Thoroughly mix Terraclor and benomyl as dust or granules into the top 2 inches of soil before planting. Or apply Terraclor or benomyl as a soil drench once after planting at 1 pint to 1 qt per sq ft.
TRANSVAAL DAISY—See Gerbera.				
TULIP				
Fire or Botrytis blight or gray-mold	Botran, 75% WP chlorothalonil benomyl, 50% WP mancozeb Ornalin, 50% WP Chipco 26019, 50% WP Topsin M	1 lb See label 1/2 lb See label 1/2-1 lb 1-2 lb See label	1 T See label 2 t See label See label 1-2 T See label	Spray several times at 5- to 10-day intervals. Start when the leaves emerge and continue to early bloom. Add a spreader-sticker to the spray to ensure wetting the foliage. Treat the soil at planting time and drench the soil before emergence using Botran or benomyl at 1 T per gal. Ornalin may also be used as a bulb dip (1-1/2 to 2 lb per 100 gal).
Bulb rots	PCNB (Terraclor), thiram, 50-75% WP, or Truban, or Terrazole + benomyl, 50% WP, or Mertect 340-F, 42.28% L Ornalin, 50% WP Topsin M	See label See labels 1-2/3 30 fl oz 1-1/2 to 2 lb See label	See label See labels 2 T See label See label See label	Before planting, dip bulbs for 5 minutes in a Terraclor, Mertect, Topsin M, or Ornalin suspension or 15 to 30 minutes in benomyl or Mertect 340-F in water at temperature of 80° to 85°F. Or dust bulbs thoroughly with thiram. See remarks on root rot complex of lily.
VERBENA				
Rhizoctonia stem and root rot	PCNB (Terraclor) benomyl, 50% WP Banrot	See label See label See label	See label See label See label	Thoroughly mix Terraclor or Banrot into top 2 inches of soil before planting. Or apply Terraclor, Banrot, or benomyl as a soil drench once after planting at 1 pint to 1 qt per sq ft.

See footnotes at the beginning of Table 3.

Flower and disease	Chemicals for control[a]	Rate[b] 100 gallons	Rate[b] 1 gallon	Remarks[c]
VERBENA, cont.				
Fungal leaf spots	Duosan, 75% WP	1-1/2 lb	See label	Spray foliage several times
	Zyban, 75% WP	1-1/2 lb	See label	at 10-day intervals during
	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	wet periods. Start when
				disease first appears.
Powdery mildew	Rubigan A.S., 11% L	3-5 fl oz	See label	Make two or more applications 10 to 14 days apart.
Nematodes	Vydate 2L	See label	See label	See African Violet.
VINCA—See Periwinkle.				
VIOLA, VIOLET—See Pansy.				
ZINNIA				
Alternaria leaf spot or blight	mancozeb	See label	See label	Spray foliage weekly
	maneb	See label	See label	during rainy periods in
	Duosan, 75% WP	1-1/2 lb	See label	spring and early summer.
	Zyban, 75% WP	1-1/2 lb	See label	Start when disease first
	Chipco 26019, 50% WP	1-2 lb	1-2 T	appears or when plants are 6 to 12 inches tall. Treat seed with captan 50% WP. Sanitation is important.
Powdery mildew	triforine (Funginex)	See label	See label	Thoroughly spray the foliage
	Duosan, 75% WP	1-1/2 lb	See label	at 7- to 10-day intervals.
	Zyban, 75% WP	1-1/2 lb	See label	Start when mildew first
	benomyl, 50% WP	1/2 lb	2 t	appears. Adding a commercial
	Karathane, 19.5% WP	1/4 lb	1 t	spreader-sticker (surfactant) to the spray usually aids in
	chlorothalonil	See label	See label	disease control. Milban is a
	Bayleton, 25% WP	2-4 oz	See label	restricted-use pesticide.
	Milban, 39% EC	See label	See label	
	Rubigan A.S., 11% L	3-5 fl oz	See label	
Botrytis blight or gray-mold	benomyl, 50% WP	1/2 lb	2 t	Spray the foliage several
	Ornalin, 50% WP	1/2-1 lb	See label	times at 10- to 14-day intervals
	Chipco 26019, 50% WP	1-2 lb	1-2 T	during cool, damp, overcast weather. Sanitary measures are
	Duosan, 75% WP	1-1/2 lb	See label	very important.
	Zyban, 75% WP	1-1/2 lb	See label	
	chlorothalonil	See label	See label	
	mancozeb, 80% WP	1-1/2 lb	1-1/2 T	
Root and stem rot complex	Banrot	See label	See label	Thoroughly drench the soil around established plants once. Use 1
	Banol, Subdue, Terrazole, or Truban +	See labels	See labels	pint to 1 qt of spray mix per sq ft of bed. Or blend granules into soil
	PCNB (Terraclor), 75% WP	1/2 lb	2 t	just before planting. Apply Chipco 26019 at seeding and at transplant
	Chipco 26019, 50% WP	6-1/2 oz	See label	time to control *Rhizoctonia*.

See footnotes at the beginning of Table 3.

MULTIPLE PESTS

1990 Turfgrass Pest Control

IMPROVED MANAGEMENT TECHNIQUES and new, more effective materials have made turfgrass culture a highly sophisticated technology. Proper irrigation, mowing, core aerification, thatch removal, and fertilization practices remain the principal defenses against turfgrass pests, but it is sometimes necessary to control weeds, diseases, and insects with the intelligent selection and use of pesticides.

Pesticide formulations. Pesticides are active against one or more turfgrass pests. These chemicals are generally formulated as liquid concentrates — solutions (S) or emulsifiable concentrates (EC); as wettable powders (WP); flowables (F); and as granules (G), wettable dispersable granules (WDG), and dispersable granules (DG). Liquid concentrates and wettable powders are usually added to water and applied to the turf with a sprayer. Granular materials can be applied with a fertilizer spreader.

Active ingredients. Pesticides must be accurately applied at correct rates to yield optimum results. Too little may control pests ineffectively; too much may injure the turf. The specific amount of material that should be applied depends upon the concentration of the pesticide (the "active ingredient") in the commercial preparation.

Concentration is usually expressed as a weight per unit volume or as a percent of the commercial preparation. For example, a 50 percent wettable powder is 50 percent active ingredients (a.i.) and 50 percent inert carrier. If the recommended rate of application is 12 pounds a.i. per acre, then 24 pounds of this commercial preparation are required to treat one acre. This is roughly equivalent to ½ pound per 1,000 sq. ft. (43,560 sq. ft. = 1 acre).

Liquid formulations generally list the number of pounds of the active ingredient per gallon (lb. a.i./gal.) on the pesticide label. For example, if the concentration is 4 lb./gal., then 1 quart of the product is required per acre to supply 1 pound of active ingredient per acre.

Precautions. Pesticides should be stored in their original containers with the label securely attached. Keep them in a cool, dry place that is inaccessible to children, pets, and irresponsible persons. **Read the label before using the pesticide and follow all instructions carefully.** A few minutes spent studying the information on the label may prevent misuse and needless accidents.

WEED CONTROL

Herbicides control one or more plant species. They may be classified into one of three types — contact, systemic, or soil sterilant — depending upon the nature of their activity on plants.

BROADLEAF WEED CONTROL IN TURF

Table 1a. — Postemergence Herbicide Control for Selected Broadleaf Weeds

All herbicides listed below should be applied when weeds are actively growing. Turfgrass species exhibit different tolerances to these herbicides. Follow label directions for appropriate turfgrass species, rates, timing, and degree of safety when used near trees and shrubs.

	2,4-D[1]	MCPP[2]	dicamba[3]	Combination of first 3 materials	2,4-D + triclopyr	2,4-D + 2,4DP	triclopyr + chlorpyrali d
black medic	..	xo	x	x	x	x	..
carpetweed	x	xo	x	x	x	..	..
chickweed							
common	..	xx	x	x	x	x	..
mouse-ear	..	xx	x	x	x	x	..
chicory	x	x	x	x	x	x	..
daisy, oxeye	xo	xo	xo	xo	..	..	..
dandelion	x	xx	x	x	x	x	x
dock, curly	xo	..	x	x	x	x	x
ground ivy	..	xo	xx	x	xx	x	xx
hawkweed	xx	..	xx	x	..	x	..
henbit	xo	xo	x	x	x	x	x
knotweed	..	xo	x	x	..	x	..
lambsquarters	x	x	x	x	x	x	..
mallow, roundleaf	..	xo	xx	x	x	x	..
pearlwort, birdseye	..	..	x	..	..	..	..
plantain							
broadleaf	x	..	..	x	x	x	x
buckhorn	x	..	..	x	x	x	x
purslane	xo	..	x	x	..	x	..
red sorrel	..	..	x	x	..	xo	..
speedwell,							
*creeping	..	..	..	xo	..	..	..
purslane	xo	xo	xo	x	xx	x	..
spurge, prostrate	..	xo	xx	x	x	xx	..
thistles	xx	xo	x	xo	x	x	x
violet	..	..	..	..	xx	xo	xx
white clover	xo	x	x	x	x	x	x
wild carrot	x	xx	x	x	x	x	..
wild onion	xo	..	xx	x	..	x	..
woodsorrel, yellow	xo	xo	xo	x	x	xx	xx
yarrow	xo	..	x	x	x	xx	..

NOTES:
.. Lack of a rating for herbicide weed combinations indicates that information was not available at time of publication.
x Usually provides adequate weed control.
xx Multiple applications may be necessary for control.
xo May only provide partial weed control.
* May be controlled with postemergence applications of DCPA.

Contact herbicides kill plant parts covered by the chemical. *Systemic herbicides,* absorbed by plant organs and translocated throughout the plant, may be either *selective,* killing certain weeds without injuring desirable grasses, or *nonselective,* controlling all vegetation.

Glyphosate, a nonselective herbicide, is useful in renovating turfs infested with extensive populations of annual weeds. Glyphosate is also used to kill perennial

Table 1b. — Preemergence Control for Selected Broadleaf Weeds

Apply these herbicides prior to weed seed germination. Read and follow label directions for appropriate turfgrasses species, timing, and application rates.

Herbicide	Weeds Controlled	Comments
isoxaben (Gallery)	Many (see label for recommendations)	Do not use on putting greens.

The following preemergence herbicides are commonly used to control annual grasses in turf. They have also been shown to have some control activity on the broadleaf weeds listed.

Herbicide	Weeds Controlled	Comments
DCPA (Dacthal)	spotted and prostrate spurge	Do not use on putting greens or putting green height bentgrasses. Second application may be necessary.
pendimethalin (LESCO Pre-M, Scotts Turf Weedgrass Control)	prostrate spurge, yellow wood sorrel, knotweed, chickweed, henbit	Avoid use on bentgrass. Second application may be necessary.
oxadiazon (Ronstar)	yellow woodsorrel	Avoid use on wet turf, red fescue, and creeping bentgrass.

weedy grasses, such as quackgrass, that cannot be controlled by selective herbicides. Because glyphosate has no residual soil activity, treated areas may be reseeded soon after application. Mecoprop is a selective herbicide used to control broadleaf weeds in turf.

Soil sterilants are chemicals that render the soil toxic to all plant life. How long the soil remains sterile depends upon the material used, the rate of application, and the prevailing environmental conditions that affect decomposition of the herbicide in the soil. Soil sterilants have no place in turfgrass management; however, they are useful in preventing plant growth under fences and other areas that are difficult to mow.

Herbicides may be applied to prevent weeds from infesting a turf or to control weeds already present. Bensulide is a *preemergence* herbicide applied in spring to prevent development of crabgrass. Once the weed has germinated, DSMA may be used as a *postemergence* treatment to selectively control the crabgrass invader.

INSECT CONTROL

Insecticides are pesticides that reduce insect populations below levels injurious to turf. Most commonly used materials are contact poisons. Effective control depends on ensuring contact between insect and insecticide. Control of soil insects (such as grubs) is achieved by drenching the insecticide into the soil, whereas foliar-feeding insects (e.g., sod webworms) are controlled by foliar sprays with no irrigation or rainfall for at least 24 hours afterwards.

Most insecticides are applied after early signs of injury are observed. No insecticide controls all turf pests. Identify the specific insect before attempting control with an insecticide. Learn to recognize early signs of injury to avoid large-scale loss of turf.

Herbicide Trade Names for Broadleaf Weed Control in Turf[a]

2,4-D
Amine 40, Decamine 4D, Dymec Turf Herbicide, Four Power, LESCO A-4D, Turf Weedestroy-D, Weedone LV4, Weedar 64

Mecoprop (MCPP)
Lescopex, MCPP Green, Mecomec, Weedestroy MCPP, Weedone MCPP

dicamba
Banex, Banvel, ProTurf K-O-G Weed Control

chlorflurenol
Break-Thru

triclopyr
Turflon Amine, Turflon Ester

2,4-D + dicamba
Four Power Plus, Triple "D", LESCO Eight-One Selective Herbicide, Super D Weedone, 101 Weedkiller, 81 Selective WeedKiller

2,4-D + mecoprop
Lescopar, Riverdale Granular Lawn Weed Killer, 4-D Amine, MCPP+2, 2 Plus 2 (MCPP + 2,4-D Amine), 2 MCPP + 2D Amine, Turf Kleen

2,4-D + dichlorprop (2,4-DP)
Agway Granular Lawn Weedkiller, LESCO Granular Herbicide, Weedone DPC, Weedone DPC Amine

2,4-D + triclopyr
Turflon D, Turflon II Amine

2,4-D + mecoprop + dicamba
LESCO Three Way, MecAmine-D, Three-Way Lawn Weed Killer, Trex-San, Trimec

2,4-D + dichlorprop + dicamba
Super Trimec

2,4-D + mecoprop + dichlorprop
Triamine Lawn Weedkiller, Weedestroy Triamine, Weedestroy Tri-ester

triclopyr + chlorpyralid
Confront

isoxaben
Gallery

DCPA
Dacthal

pendimethalin
LESCO Pre-M, Scotts Turf Weedgrass Control

oxadiazon
Ronstar

[a] This is not an exhaustive list of trade names for herbicides used on turf. We will amend this list in future reprints if we are notified of products with similar composition.

Label registrations can change at any time. Thus, the recommendations in this circular may become invalid. The user is encouraged to carefully read and follow the most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

DISEASE CONTROL

Fungicides kill or inhibit the growth of fungi. Fungicides are of two general types: protective-contact and systemic.

Protective-contact fungicides are applied to seed, foliage, or soil to keep disease-causing fungi from entering grass plants. They must be applied at 5- to 14-day intervals since mowing, rain, and irrigation soon remove much of the surface chemical. Relatively high spray volumes (3 to 5 gal. water per 1,000 sq. ft.) supplies uniform coverage of the foliage. A surfactant added to the spray increases coverage. Many turf fungicides are the protective-contact type. Examples of protective-contact fungicides include: Calo-Clor and Calo-Gran; captan; Chipco 26019; Daconil and Thal-O-Nil; Dyrene, Lescorene, or Dymec; ethazole (Koban, Terrazole); maneb; mancozeb, Lesco 4, or Fore; PCNB (Terraclor, Turfcide); and thiram (Thiramad, Spotrete).

Systemic fungicides are absorbed and distributed within plants destroying established infections and controlling certain diseases for several weeks or months. These fungicides are absorbed principally by the roots and should be drenched or watered in. Examples of systemic fungicides include: Aliette, Apron, Banner, Bayleton, Cleary 3336, Fungo 50, Rubigan, Subdue, Teremec SP and Terraneb SP, Tersan 1991, and Vorlan.

Combinations of protective-contact and systemic fungicides include Bromosan and Duosan.

Table 2. — Herbicides for Control of Selected Annual Grassy Weeds in Turf

Herbicides listed below are used to control annual grasses in turf. Always follow the label directions for application rates and proper timing. For extended preemergent control of annual grass weeds, apply a second application 6 weeks after initial application at ½ the original rate. The common name of the chemical is listed first; the names in parentheses are trade names.

	Preemergent	Postemergent	Annual bluegrass	Crabgrass, foxtails, barnyardgrass	Goosegrass	Remarks
benefin (Balan)	x	. .	ls	es	. .	Avoid use on bentgrass.
benefin and trifluralin (Team)	x	. .	ls	es	. .	Avoid use on bentgrass.
bensulide (Betasan)	x	. .	ls	es	. .	
DCPA (Dacthal)	x	. .	ls	es	es, ej	May injure fine-leaf fescues or bentgrass, especially Cohansey or Toronto. Goosegrass is difficult to control; complete control is rarely achieved. Better control may result if an early application is followed by a second at half the rate in early June.
ethofumesate (Prograss)	x	x	es, ls	. .	. .	See label for specific uses.
fenoxaprop (Acclaim)	. .	x	. .	*	*	Avoid use on bentgrass and young Kentucky bluegrass. May injure some mature Kentucky bluegrass cultivars.
oxadiazon (Ronstar)	x	. .	. .	es	es	Avoid use on red fescue, bentgrass, and wet turf.
organic arsenicals (DSMA — Arrhenal, Weed-E-Rad 360; and MSMA — Arsonate, Daconate 6, Weed Hoe)	. .	x	. .	*	*	May discolor turfgrass. Apply soon after emergence. May require three applications at 7- to 10-day intervals.
pendimethalin (Scotts Turfgrass Weed Control, LESCO Pre-M)	x	. .	ls	es	. .	Avoid use on bentgrass and annual bluegrass turf.
siduron (Tupersan)	x	. .	. .	es	. .	May injure some bentgrasses or fine fescues. Do not use on Bermudagrass. Can be used at ½ rate in conjunction with bluegrass seeding.

es — Apply in early spring before weed emergence.
ls — Apply in late summer.
ej — Apply in early June.
* — See label for appropriate rates and timing of application.

Table 3a. — Nonselective Postemergence Herbicides for Control of Perennial Grassy Weeds in Turf[a]

Use nonselective postemergence herbicides for spot control only. Nonselective herbicides will kill or damage desirable turf.

Weeds	Control	Comments
e.g., nimblewill, bentgrass bermudagrass, quackgrass, tall fescue	amitrole (Amitrol-T)	May persist in soil up to 4 weeks. Do not plant new turf in treated areas for 4 weeks following application.
	dalapon (Dalapon 85, Dowpon M)	May persist in soil up to 6 weeks. Do not plant new turf in treated areas for 6 weeks following application.
	glyphosate (Roundup, Kleenup)	Has no residual activity in soil; seeding can follow treatment immediately. However, it is suggested to wait 1 week to allow translocation of the herbicide. Repeat applications of glyphosate may be required for complete control.

[a] Apply these herbicides when weeds are actively growing.

Table 3b. — Selective Postemergence Herbicides for Control of Perennial Grassy or Grasslike Weeds in Turf[a]

Weeds	Control	Comments
tall fescue	chlorsulfuron (LESCO TFC)	For spot treatment with hand-held sprayer in established Kentucky bluegrass, fine fescues, and bentgrass (mowed taller than ½ inch). Avoid using when drift may occur. For nonselective tall fescue control in perennial ryegrass, use amitrole, dalapon, or glyphosate.
yellow nutsedge	bentazon (Basagran)	Apply soon after emergence to actively growing nutsedge. Repeat applications may be necessary up to a total of 3 lb. a.i./A. per season.

[a] Apply these herbicides when weeds are actively growing.

Table 4. — Chemical Control of Turfgrass Diseases

Diseases[a]	Principal turfgrasses affected	Normal season and intervals of application	Fungicide preparations (oz. per 1,000 sq. ft.)[b]
"Helminthosporium" diseases			
Leaf spot, Melting-out (*Drechslera poae*)	Kentucky bluegrass	March-June; Sept.-Nov. 7 to 21 days	Bromosan-F (5 to 8 fl. oz.) Chipco 26019 WP 50% or FLO (2 to 4 oz.) Daconil 2787 WP 75% or 500L (3 to 11 oz.) Duosan WP 75% (3 to 6 oz.) Dyrene 4F or Dymec WP 50% (2 to 4 oz.) Fore or Formec 80 WP 80% (4 to 6 oz.) PCNB (Terraclor) WP 75% (see label) Vorlan WP 50% (2 oz.) Turfcide 10G (5 to 7½ lb.) Turfcide 24% EC (1 to 1½ qt.) maneb, 80% WP (3 to 8 oz.) mancozeb, 80% WP (3 to 8 oz.) mancozeb 4L, 37%L (5 to 14 fl. oz.)
Leaf spot, crown and root rot (*Bipolaris sorokiniana*)	All turfgrasses	May-Oct. 7 to 21 days	
Zonate eyespot (*Drechslera gigantea*)	Bermudagrass Bluegrasses Bentgrasses	June-Sept. 7 to 21 days	
Net blotch, crown and root rot (*Drechslera dictyoides*)	Fescues Ryegrasses	March-July 7 to 21 days	
Brown blight (*Drechslera siccans*)	Ryegrasses	April-June 7 to 21 days	
Leaf blotch (*Bipolaris cynodontis*)	Bermudagrass	March-June 7 to 21 days	
Red leaf spot (*Drechslera erythrospila*)	Bentgrasses	April-Sept. 7 to 21 days	
Summer patch and necrotic ring spot (*Magnaporthe paae* and *Leptosphaeria korrae*)	Bentgrasses Bluegrasses Fescues Ryegrasses Bermudagrass	April-Sept. (see labels)	Banner L 14.3% (4 fl. oz.) *or* Rubigan A.S. 11%L (2 to 8 fl. oz.) *plus* Bayleton DP 25% (2 to 4 oz.), Chipco 26019 WP 50% or FLO (4 to 8 oz.), Cleary 3336 (see label), Fungo WP 50% (4 to 8 oz.), Tersan 1991 WP 50% (5 to 8 oz.), or Topsin M (see label)

Comments: Apply when disease is expected or first appears. Repeat in 14 to 30 days if necessary. Drench fungicide into root zone using ½ inch (300 gal.) to 1 inch (600 gal.) of water per 1,000 sq. ft. Water the turf thoroughly the day before (300 to 450 gal. water per 1,000 sq. ft.).

[a] Causal fungus listed in parentheses.

[b] Denotes either fungicide, coined name, or representative trade names. Mention of a trade name or proprietary product does not constitute warranty of the product and does not imply approval of this material to the exclusion of comparable products that may be equally suitable. Except where indicated, all materials should be applied in 3 to 5 gal. of water per 1,000 sq. ft. Use lower fungicide rates in *preventative* programs, higher rates for *curative* programs. Only one from each recommended group of preparations need be used. Fungicide use and restrictions are subject to change without notice. Always read and follow the current package label instructions and precautions.

Table 4. — Chemical Control of Turfgrass Diseases (continued)

Diseases[a]	Principal turfgrasses affected	Normal season and intervals of application	Fungicide preparations (oz. per 1,000 sq. ft.)[b]
Dollar spot (*Lanzia* and *Moellerodiscus* spp.)	All turfgrasses	May-Nov. 7 to 30 days (see labels)	Banner L 14.3% (1 to 2 fl. oz.) Bayleton DP 25% (1 to 2 oz.) Bromosan-F (4 fl. oz.) Chipco 26019 WP 50% or FLO (2 to 4 oz.) Daconil 2787 WP 75% or 500L (3 to 11 oz.) Duosan WP 75% (3 to 5 oz.) Dyrene 4F or Dymec WP 50% (4 to 8 oz) Rubigan A.S. 11%L (¾ to 1½ fl. oz.) Vorlan WP 50% (1 to 2 oz.)
Red thread or pink patch (*Laetisaria fuciformis* and *Limonomyces roseipellis*)	All turfgrasses	April-June; August-Nov. 7 to 30 days (see labels)	
Comments: Resistance to benomyl, thiophanate materials, Dyrene, and other fungicides has been reported in some areas. Using combinations of active ingredients or alternating between products is advisable.			
Rhizoctonia brown patch or blight (*R. solani*)	All turfgrasses	May-Oct. 5 to 21 days (see labels)	Banner L 14.3% (2 to 4 fl. oz.) Chipco 26019 WP 50% or FLO (2 to 4 oz.) Daconil 2787 WP 75% or 500L (3 to 11 oz.) Duosan 75% WP (4 to 6 oz.) Dyrene 4F or Dymec WP 50% (4 to 8 oz.) Fungo WP 50% (2 to 3 oz.) Rubigan A.S. 11%L (1½ fl. oz.) + Daconil 2787 or Chipco 26019 (see labels) Tersan 1991 WP 50% (1 oz.) + Daconil 2787 (see label) Vorlan WP 50% (2 oz.) + Fungo WP 50% (2 oz.)
Rusts: leaf and stem (*Puccinia* spp.)	All turfgrasses, especially certain cultivars of Kentucky bluegrass, Perennial ryegrass, Zoysiagrass, and Bermudagrass	June-Oct. 7 to 28 days (see labels)	Banner L 14.3% (1 to 2 fl. oz.) Bayleton DP 25% (1 to 2 oz.) Daconil 2787 WP 75% or 500L (6 to 11 oz.) Duosan WP 75% (4 to 6 oz.) Dyrene 4F or Dymec WP 50% (4 to 8 oz.) maneb (see label) mancozeb 4L, 37%L (5 to 7 fl. oz.)
Anthracnose (*Colletotrichum graminicola*)	All turfgrasses, especially annual bluegrass	May-Oct. 7 to 30 days (see labels)	Banner L 14.3% (1 to 2 fl. oz.) Bayleton DP 25% (2 oz.) Daconil 2787 WP 75% or 500L (5 to 11 oz.) Duosan WP 75% (3 to 5 oz.) Fungo WP 50% (2 oz.) + Vorlan WP 50% (2 oz.) Rubigan A.S. 11%L (1¾ to 3½ fl. oz.) Tersan 1991 WP 50% (1 to 2 oz.)
Leaf smuts Stripe smut (*Ustilago striiformis*) Flag smut (*Urocystis agropyri*)	All turfgrasses, especially certain bentgrasses, bluegrasses, and ryegrasses	Oct.-Nov. (see labels)	Banner L 14.3% (1 to 2 fl. oz.) Bayleton DP 25% (2 oz.) *or* Fungo WP 50% (6 to 8 oz.) *or* Rubigan A.S. 11%L (15 fl. oz.) *or* Tersan 1991 WP 50% (6 to 8 oz.) *plus* PCNB (Terraclor) WP 75% (see label)
Comments: Make one or two applications, 14 to 21 days apart. Drench fungicide into soil, using 1 inch (600 gal.) water per 1,000 sq. ft., immediately after application.			
Powdery mildew (*Erysiphe graminis*)	Bluegrasses Bermudagrass Fescues	March-Nov. 7 to 30 days (see labels)	Banner L 14.3% (1 to 2 fl. oz.) Bayleton DP 25% (1 to 2 oz.) Rubigan A.S. 11%L (2 to 4 fl. oz.)
Snow molds Typhula blight (*T.* species) Fusarium patch (*Microdochium nivalis*)	All turfgrasses	Nov.-March see labels for interval	Bayleton DP 25% (4 oz.) Chipco 26019 WP 50% or FLO (2 to 8 oz.) Calo-Clor, Calo-Gran (see label)[c] Daconil 2787 WP 75% or 500L (8 to 16 oz.) Rubigan A.S. 11%L (8 fl. oz.) Teremec SP or Terraneb SP WP 65% (6 to 9 oz.) *plus* PCNB (Terraclor) WP 75% (8 oz.)
Pythium blight, grease spot, spot blight (many *P.* species)	All turfgrasses	April-Nov. 5 to 21 days (see labels)	Banol L 66.5% (1⅓ to 4 fl. oz.) Koban 30% WP (2 to 8 oz.) Subdue 2E (1 to 2 fl. oz.) Terrazole WP 35% (4 to 8 oz.) Teremec SP or Terraneb SP WP 65% (4 to 6 oz.) Chipco Aliette WP 80% (4 to 8 oz.)

[c] Cleared for use *only* on golf course greens, aprons, and tees by certified golf course superintendents.

Table 4. — Chemical Control of Turfgrass Diseases (continued)

Diseases[a]	Principal turfgrasses affected	Normal season and intervals of application	Fungicide preparations (oz. per 1,000 sq. ft.)[b]
Fairy rings (*Marasmius oreades, Agaricus* or *Psalliota campestris, Chorophyllum [Lepiota]* species, *Trechispora alnicola*)	All turfgrasses		methyl bromide chloropicrin Vapam Soil Fumigant Vorlex or Vorlex 201 formaldehyde
Comments: Soil temperature should be above 60°F. for fumigation. Cover area with gasproof cover for several days, *or* instead of treating with a soil fumigant, use root feeder attachment on hose to drench rings with water. Repeat when symptoms reappear.			
Seed rot, damping off, seedling blights (*Pythium* sp., *Fusarium* sp., *Rhizoctonia solani, Drechslera* and *Bipolaris* spp.; *Colletotrichum graminicola*)	All turfgrasses	Treat seed before planting.	captan *or* thiram 50% or 75%, *plus* Koban WP 30% *or* Apron 25W
		Spray just after seeding, at early seedling emergence, and 7 to 14 days later (see labels).	Koban WP 30%, Banol L 14.3%, Subdue 2E, or Terrazole WP 35% *plus one of these:* captan WP 50% Chipco 26019 WP 50% Dyrene 4F *or* Dymec WP 50%
Nematodes (many genera and species)	All turfgrasses	fenamiphos [Nemacur or 10G] (except zoysia) or ethoprop [Mocap 10G, Nematicide-Insecticide, Proturf Nematicide-Insecticide] (except bentgrass).	
Comments: Follow the manufacturer's directions carefully. Follow nematicide *immediately* with at least ½ inch of water to ensure penetration into soil to prevent toxic effects. Treat in fall or spring (or both, if nematodes are a serious problem) when soil temperature is above 55°F. Make no more than two applications per year. Aerifying turf before application improves results. *Do not apply to newly seeded areas.* For use only by certified pesticide applicators.			
Slime molds (*Physarum cinereum, Fuligo* sp., *Mucilago spongiosa, Stemonitis* spp.)	All turfgrasses	May-Sept. Mow, rake, pole, or hose down to remove mold when seen. Controlled by any fungicide listed for "Helminthosporium" diseases.	
Algae, green or black scum	All turfgrasses	Apply when first seen; reapply as needed.	copper sulfate (1 to 2 oz.) Daconil 2787 WP 75% or 500 (4 to 11 oz.) mancozeb WP 80% (6 oz.)
Moss	All turfgrasses	Apply when first seen; reapply as needed.	ferrous ammonium sulfate (1 to 4 lbs.) ferric sulfate (1 to 4 lbs.)

[a] Causal fungus listed in parentheses.
[b] Denotes either fungicide, coined name, or representative trade names. Mention of a trade name or proprietary product does not constitute warranty of the product and does not imply approval of this material to the exclusion of comparable products that may be equally suitable. Except where indicated, all materials should be applied in 3 to 5 gal. of water per 1,000 sq. ft. Use lower fungicide rates in *preventative* programs, higher rates for *curative* programs. Only one from each recommended group of preparations need be used. Fungicide use and restrictions are subject to change without notice. Always read and follow the current package label instructions and precautions.

Table 5. — Chemical Control of Insects

Insect	Insecticide[a]	Formulation[b]	Suggestions
Annual white grubs	diazinon trichlorfon (Dylox, Proxol) isofenphos (Oftanol) bendiocarb (Turcam) isozofos (Triumph)	EC or G SP or G G or EC WP EC	Sample for grubs in several areas of infested turf. Ten to 12 grubs or more per square foot are necessary to justify treatment. Apply as spray or granules to a small area and then drench in thoroughly before treating another small area. White grub damage will usually occur in August through October. Diazinon is not labeled for use on golf courses and sod farms. Triumph is labeled for use only on home lawns, sod farms, golf course tees, greens, and aprons.
Ataenius grubs	trichlorfon (Dylox, Proxol) isofenphos (Oftanol) bendiocarb (Turcam) isozofos (Triumph)	SP or G G or EC WP EC	Apply as spray or granules and drench into infested soil. Fifty or more ataenius grubs per square foot are necessary for damage to high-quality turfgrass. Triumph is labeled for golf course greens, tees, and aprons. Damage first appears in mid-June to early July and again in late August.

[a] Use one of the insecticides recommended for a given group of insects, being sure to use the proper dosage for the formulation chosen. Follow labels as to correct rate of application.
[b] EC = emulsion concentrate; WP = wettable powder; G = granules; SP = soluble powder.

Table 5. — Chemical Control of Insects (continued)

Insect	Insecticide[a]	Formulation[b]	Suggestions
Billbugs	chlorpyrifos (Dursban) isofenphos (Oftanol)	EC EC or G	Billbugs are a problem in turfgrass only in a few counties in Illinois. These locations are in the greater Chicago area and East St. Louis area. Control adult billbugs in April with a foliage treatment. Drench treatment into soil in June or July for larval control.
Cicada killer and other soil-nesting wasps Ants	diazinon chlorpyrifos (Dursban)	EC EC	Apply as spray or granules and water in thoroughly. For individual nests pour 1% diazinon in nest and seal in with dirt.
Sod webworms Armyworms Cutworms	carbaryl (Sevin) diazinon chlorpyrifos (Dursban) trichlorfon (Dylox, Proxol)	WP or G EC or G EC or G SP or G	Webworms usually damage lawns in late July and August. Two or more webworms per square foot can cause damage to turf. Apply as a spray using at least 2½ gal. per 1,000 sq. ft.; as granules, apply with fertilizer spreader and activate by watering.
Millipedes and sowbugs	carbaryl (Sevin) diazinon	WP or G EC or G	Spray around home where millipedes or sowbugs are crawling. If numerous, treat entire lawn.
Chinch bugs	chlorpyrifos (Dursban) diazinon trichlorfon (Dylox, Proxol)	EC EC SP	Spray infested areas in lawn where chinch bugs are present. Detect bugs by drenching small turf areas with water, causing the bugs to crawl up on the grass blades.
Greenbug	acephate (Orthene) chlorpyrifos (Dursban)	EC EC	Spray grass thoroughly if rust-colored grass appears and greenbugs are numerous at the edge of these areas.
Slugs	Mesurol	bait	Apply where slugs are numerous. Scatter in grass.

[a] Use one of the insecticides recommended for a given group of insects, being sure to use the proper dosage for the formulation chosen. Follow labels as to correct rate of application.
[b] EC = emulsion concentrate; WP = wettable powder; G = granules; SP = soluble powder.

RECORD OF PESTICIDE APPLICATIONS

Date	Chemical	Turf treated	Dosage	Remarks

Prepared by T. W. Fermanian, Associate Professor, and T. B. Voigt, Assistant Horticulturist, both Department Horticulture; M.C. Shurtleff, Professor, Department of Plant Pathology; and R. Randell, Professor, Agricultural Entomology.

1990 Insect, Disease and Weed Pest Management Guide: COMMERCIAL APPLICATION FOR TREES AND SHRUBS

Commercial arborists, urban foresters, and nurserymen find it necessary to control insects, diseases, and weeds at various times throughout the growing season in order to protect their investment and to preserve the aesthetic and social benefits of woody landscape plants.

This pest management guide has been prepared for use by Illinois commercial lawn and tree care personnel, municipal arborists, urban foresters, and nursery operators--it is not for homeowners or home gardeners. Furthermore, the commercial applicator is usually required to use a greater variety of pesticides and at higher rates in order to achieve effective control.

INTEGRATED PEST MANAGEMENT

A pest management program includes the wise and timely selection of cultural, mechanical, biological, and chemical control measures to ensure maximum effectiveness against the pest and to minimize cost and environmental effects.

In some cases, chemical control may not be necessary. Planting of resistant varieties and utilization of natural enemies or cultural methods may provide adequate control. In other cases, with high-value specimen plants, chemicals may be an integral part of the pest management program. Familiarization with the habits and life history of the pest will aid in these decisions.

CLASSIFICATION OF PESTICIDES

Pesticides are classified as either general-use or restricted-use by the U.S. Environmental Protection Agency. A person wishing to use a restricted-use pesticide must first be certified as a commercial pesticide applicator by the Illinois Department of Agriculture. Contact your local county Extension adviser for details of the certification program. Some of the products listed in this circular are restricted-use and others may become restricted-use in the near future. Therefore, check with your local county adviser if you are in doubt about the status of a particular pesticide. In some cases, decisions covering the present status of certain chemicals may be pending. Every effort will be made to keep you informed of any label changes or reclassifications via announcements in newsletters, the news media, grower meetings, and pesticide training clinics.

This publication presents the insect, disease, and weed control application intervals and rates for various crops as approved by the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA) as of September 1, 1989, to the best of our knowledge.

Label registrations can change at any time. Thus, the recommendations in this circular may become invalid. The user is encouraged to carefully read and follow the most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

PESTICIDE NAMES

The chemical names used in the tables may be unfamiliar to you. Pesticides have chemical, common, and trade names. A pesticide has only one common name but may have several trade names, depending on which company or companies market the product. To assist you in identifying a particular pesticide, common names and corresponding trade names are listed on the last page of this paper.

This circular was prepared by Roscoe Randell and Phil Nixon, Extension entomologists, Malcolm Shurtleff, Extension plant pathologist, and Dave Williams, Extension horticulturist.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
Circular 1264-90
October 1989

PROPER USE OF PESTICIDES

In using pesticides, be sure first to read the label and carefully follow label directions. Do not exceed the maximum rates suggested; observe carefully the proper timing for applying the pesticide and apply it only to plant material for which it is approved. Some chemicals may prove to be phytotoxic to certain plants, so be sure to check the label. Keep a careful record of the product used, the trade name, the percent content of active ingredient of the pesticide, dilution, the rate of application, and dates of application for future reference.

PESTICIDE SAFETY

Remember, these chemicals are toxic and designed to kill the target organism. Also, be aware that hazard and toxicity are not the same! Hazard is a combination of toxicity and exposure. A chemical with low toxicity can still be hazardous if handled improperly. Some low toxic chemicals can cause blindness if splashed in the eyes, so be sure to wear the proper protective equipment as specified on the label. Other chemicals are highly toxic, so proper handling and protective equipment is a must.

Pesticides can be an effective tool in controlling pests, but they must be handled safely and effectively in order to achieve the desired results and at the same time keep human and environmental hazards to a minimum.

ADDITIONAL SOURCES OF INFORMATION

In the tables, leaflets describing the life history, biology, and habits of tree and shrub insect pests are indicated by the letters "NHE" and the leaflet number. These leaflets are available from your county Extension office or from Entomology Extension, 172 Natural Resources Bldg., 607 E. Peabody Drive, Champaign, IL 61820. The cost of each NHE leaflet is 15 cents. Checks should be made payable to the University of Illinois. Other pest management publications are available from the Office of Agricultural Publications, 54 Mumford Hall, 1301 W. Gregory Drive, Urbana, IL 61801. These include Circular 900, *1990 Insect Pest Management Guide: Home, Yard, and Garden;* Circular 1260, *1990 Plant Disease Control Guide: Woody Ornamentals,* and *1990 Chemical Weed Control.*

GENERAL DISEASE CONTROL SUGGESTIONS FOR MOST WOODY ORNAMENTALS*

Diseases	Chemicals for control	Remarks
Damping-off Seed rot or decay Seedling blights	Captan, metalaxyl (Subdue), etridiazole (Truban or Terrazole), iprodione (Chipco 26019), Banrot	Apply captan as a seed treatment any time before planting. Grow plants in sterilized (pasteurized) soil wherever feasible. Mix metalaxyl + Banrot, iprodione, and etridiazole into soil or apply as drenches. Check labels for crop registrations.
Storage decay	Captan, Botran, benomyl, Ornalin, or PCNB (Terraclor)	Spray, dust, or dip plants, and other plant parts before shipping or placing in storage. Check labels for crop registrations.
Cutting rots Damping-off Seedling blights Crown (foot) rots Stem rots Root rots	PCNB (Terraclor), captan-PCNB mixtures, Banrot, benomyl (Benlate), PCNB-etridiazole (SA Terraclor Super-X), or thiophanate-methyl (Topsin M)	For Botrytis, Rhizoctonia, Sclerotinia, and Sclerotium stem and root rots only. Apply as a soil drench at 1 pint to 1 quart per sq ft or work into upper 2 to 4 inches of soil before planting. Check labels for crop registrations.

Diseases	Chemicals for control	Remarks
Cutting rots Damping-off Seedling blights Crown (foot) rots Stem rots Root rots *(continued)*	Propamocarb (Banol), fosetyl-Al (Aliette), etridiazole (Truban or Terrazole), Banrot, metalaxyl (Subdue), or PCNB-etridiazole (SA Terraclor Super-X)	For Aphanomyces, Phytophthora, and Pythium stem and root rots (water molds) only. Usually applied as a soil drench at intervals of 2 to 8 weeks. Check labels for current crop registrations. Sometimes combined with PCNB (Terraclor).
Leaf, stem, and flower spots, blotches, and blights caused by fungi Anthracnoses Scabs	Benomyl + captan, maneb, mancozeb, chlorothalonil (Daconil 2787, Exotherm Termil), Kocide 606, Zyban, Duosan, vinclozolin (Ornalin), triforine (Funginex), iprodione (Chipco 26019), triadimefon (Bayleton), dodine (Cyprex), or thiophanate-methyl (Topsin M)	Benomyl plus captan, chlorothalonil, or mancozeb also gives *Botrytis* control, as does vinclozolin, Zyban, Duosan, and iprodione. Applications are needed at intervals of 5 to 7 days in rainy weather and 7 to 10 days in drier weather. Check labels for specific information and crop registrations.
Rusts	Maneb, mancozeb, triadimefon (Bayleton), triforine (Funginex), Rubigan, or chlorothalonil (Daconil 2787)	Applications usually needed at intervals of 7 to 10 days, starting when rust first appears. Check labels for current crop registrations.
Powdery mildews	Benomyl, sulfur, dinocap (Karathane), triforine (Funginex), Zyban, Duosan, triadimefon (Bayleton), Rubigan, or thiophanate-methyl (Topsin M)	Frequent applications and thorough coverage are essential. Cycloheximide, sulfur, and dinocap may cause plant injury, especially in hot weather at 85°F or above. Check labels for current crop registrations.
Bacterial flower, leaf, and shoot	Streptomycin formulations or copper fungicide	Strictly follow manufacturer's directions to avoid plant injury. Note label restrictions.
Wilt diseases (mostly *Fusarium* and *Verticillium*) Crown and root rots Crown gall	Steam at 180°F for 30 minutes or 160°F for 1 hour at the coolest spot or fumigate soil with methyl bromide, chloropicrin, Vorlex, or Vapam Soil Fumigant.	Treat soil several days to a month before planting. Carefully follow the manufacturer's directions as chemicals are very toxic. Some may be used only by licensed commercial applicators. Also treat containers, benches, work surfaces, potting table, tools and other equipment.

Diseases	Chemicals for control	Remarks
Fire blight	Streptomycin formulations or copper fungicide	Spray when 20 percent of blossoms are open and at 5- to 7-day intervals during bloom. Check labels for current crop registrations.
Soil nematodes (including root-knot and root-lesion nematodes)	Same as wilt diseases or apply oxamyl (Vydate 2L), Dasanit 15G, Temik 10G, Nemacur 10G or 15G	Galltrol A and Norbac 84-C are crown gall controls. Carefully follow crop registrations and directions.
Viruses Viroids Mycoplasmas Spiroplasmas	Apply insecticides at frequent intervals to keep the insects from feeding, as recommended by University of Illinois entomologists.	Control insects that transmit the causal agents, especially leafhoppers, aphids, and thrips. Rogue the first infected plants. Keep down broadleaf weeds. Keep greenhouse and nursery beds screened.

* **NOTE:** For detailed information regarding specific woody ornamentals and the chemicals suggested to control their diseases, obtain a current copy of Illinois Extension Circular 1260, *1990 Plant Disease Control Guide: Woody Ornamentals.*

The *Report on Plant Diseases* (RPD) series, numbers 600 to 659, are available from Extension Plant Pathology, N-533 Turner Hall, 1102 South Goodwin Avenue, Urbana, IL 61801. The cost of each RPD is 50 cents. Checks should be made out to the University of Illinois.

Fertilization

Unthrifty and undernourished woody ornamentals are susceptible to a variety of diseases and environmental stresses. Their vigor can often be greatly improved by periodic applications of fertilizer and timely watering. Soil tests are always suggested prior to feeding, especially if a soil or lawn fertilization program has been in effect. In general, a 10-10-10 (NPK) fertilizer is recommended at the rate of 2 to 4 pounds per inch of trunk diameter at breast height. The fertilizer can be injected into holes in the ground evenly distributed beneath the tree and extending out to the drip line or beyond. Alternatively, apply fertilizer by surface broadcasting about 1 or 2 pounds actual nitrogen per 1,000 square feet during the dormant season; ammonium nitrate or nitrate of soda are acceptable compounds.

Sanitation

Proper selection of planting site, planting method, and materials, as well as soil preparation, pruning, winter protection, disease and pest control, and avoidance of unnecessary wounding will aid in control of a wide range of diseases.

Prune during dry weather and sterilize tools frequently between cuts. Use a fresh 10 percent solution of liquid household bleach, 70 percent denatured alcohol, or radiator antifreeze-type alcohol or 4 percent formaldehyde. When pruning or removing diseased wood, paint the newly exposed inner bark and sapwood with a germicidal or fungicidal coating. Shellac is useful for many diseases. Follow the shellac with a tree wound paint containing benomyl (Benlate) fungicide, 50% WP, at the rate of 1 gram in 5,000 grams or 2-2/3 ounces per 100 gallons. This mixture, although harmless to living bark, is toxic to spores of such canker- and wilt-producing fungi as *Botryosphaeria*, *Ceratocystis*, *Cytospora (Valsa)*, and *Verticillium.*

Surfactants

Wetting, spreading, and sticking agents (surfactants) are often added to spray mixtures for hard-to-wet foliage such as on conifers, broadleaf evergreens, boxwood, and roses. Some commercial spreader-stickers available for tank mixing include Biofilm Spreader-Sticker, Chevron Spray Sticker, Citowett Plus, Filmfast Spreader-Sticker, Miller Nu-Film-P and -17, De-Pester Spreader-Activator, DuPont Spreader-Sticker, and Aqua T Non-ionic Organic Wetting Agent. Commercial spreaders include Chevron Spreader, Chipco and Rhodia Spreader-Activator, Flo-Wet, Multi-Film L and X-77, Ortho X-77 Spreader, Pinolene, Sure Spred, Surfactant II, Triton B-1956, Tween 20, Flexit, Sanomerse 80, and Penex. The pesticide label usually indicates any restrictions that should be observed in selecting compatible surfactants. Use these commercial preparations according to label directions. The addition of any extra wetting, spreading, or sticking agent may cause excess runoff and result in a poor spray deposit.

CHEMICAL WEED CONTROL RECOMMENDATIONS FOR LANDSCAPE PLANTINGS

Many landscape managers consider weeds to be their most common and bothersome pest problem. Weeds are ubiquitous, infesting beds of woody and herbaceous ornamental plants, turf areas, and cracks in paved areas such as sidewalks and parking lots.

Beside being unsightly and giving an unmanicured appearance to commercial and residential landscape sites, weeds compete with desirable ornamental plants for nutrients, light, and growing space. They also can harbor insect and disease pests; they can be fire hazards, and noxious weeds such as poison ivy and ragweed can be health hazards.

Weed management programs for landscape sites include methods for both the eradication and prevention of weeds. The goal of a successful weed control program should be to integrate cultural decisions, mechanical methods, and chemical methods into an efficient and effective strategy to control weeds with a minimum of labor, cost, and environmental hazard.

The remainder of this article concentrates on the chemical component of weed control in programs of landscape plantings of herbaceous and woody ornamental plants.

HERBICIDE SELECTION

Herbicides provide an efficient means for controlling weeds. They are precise in their activity, but satisfactory results can only be achieved if herbicides are used properly. The first step in selecting a herbicide is to identify your weed problem.

Herbicides are classified as selective or nonselective, depending on the range of plants they kill. Selective herbicides kill certain plants with little or no injury to others. This is of the utmost importance when applying herbicides to areas containing ornamental plants. Selective herbicides include both foliage- and soil-applied herbicides.

Nonselective herbicides are toxic to almost all plants. Some herbicides that are selective at a low rate may be nonselective when applied at a high rate. Nonselective herbicides are useful in areas where total vegetation control is desired, such as in industrial areas, along fences, around buildings, and in other noncrop areas. Nonselective herbicides can be either foliage- or soil-applied.

Herbicides are also classified according to when and how they are applied to the ornamental plants or weeds. *Preplant* herbicides are applied before the ornamentals are planted. They are frequently incorporated into the soil and then referred to as preplant incorporated (PPI). *Preemergence* refers to the use of a herbicide before direct-seeded ornamental plants or weeds emerge, or before the weeds appear in landscape plantings. Most soil-applied herbicides require moisture to facilitate absorption by emerging weed seedlings. Rainfall can move the herbicide into the soil and provide the moisture for absorption. Mechanical incorporation can also move the herbicide into soil, and if sufficient soil moisture is available this can mean less dependence on rainfall. Soil texture and organic matter content affect the activity of soil-applied herbicides. The residual activity of the preemergnce herbicides can vary from several weeks to several months.

Postemergence refers to the use of herbicide after the crop or weeds have emerged. Postemergence herbicides are applied to the foliage of the weeds. Most must remain on the weed foliage for several hours to be effective. If rain falls shortly after application, retreatment may be necessary. Postemergence herbicides may be broadcast *over-the-top* of both ornamental plants and weeds if they are sufficiently selective to kill weeds without significantly affecting the ornamentals. Some less selective herbicides may be applied as *directed postemergence*, when the spray is directed onto the weeds and kept off the ornamental plants as much as possible. For directed sprays, it is helpful to have a height differential with weeds smaller than the ornamental plants. Earlier cultural practices, mechanical cultivation, or herbicides can sometimes help to establish this height differential. Spot treatments are applied to individual weeds or small patches of weeds.

Herbicides are also classified by their type of activity. *Translocated* or *systemic* herbicides move (translocate) in the plant from the site of uptake. The site of uptake can be either the roots or emerging shoots when the herbicide is applied to the soil, or the foliage and/or stem when an aboveground treatment is made. Since the plant must be actively growing for these herbicides to translocate to sites of action, most are applied during the growing season. Injury symptoms may take several days to several weeks to develop, depending on the type of herbicide. Since translocated herbicides can move throughout the plant system, they are effective against annuals, biennials, and perennials. Depending on the particular herbicide, activity may be selective or nonselective. *Nontranslocated* herbicides are active at the site of absorption or contact. They do not translocate within the plant. They are either soil-applied or foliage-applied. They can be applied at various times.

Foliage-applied nontranslocated herbicides are usually called *contact* herbicides. They nonselectively kill green foliage on contact by killing the plant tissue. They can also damage the bark of young trees such as thornless honeylocust and linden. Since only the tissue actually may be killed, surfactants are often added to improve coverage of the foliage. Contact herbicides can be effective for the control of annual plants if all the growing points are aboveground and thoroughly sprayed. They will also burn back the aboveground portions of biennial and perennial plants, but regrowth may occur since these plants have growing points that are underground and therefore protected. The injury symptoms of a plant treated with a contact herbicide are usually visible within a matter of hours. Contact herbicides usually have little or no residual soil activity.

To ensure that the proper herbicide is chosen for the ornamental planting and the particular weed problem, always read the label. The label gives rates and directions for use as well as precautions to prevent possible harm to the applicator, other people, animals, and the environment.

The different herbicide categories are discussed in greater detail in the following sections.

PREEMERGENCE HERBICIDES

Alachlor (*Lasso*)* is available in emulsifiable concentrate, microencapsulated, and granular formulations. It is labeled for use on a limited number of woody plant species. Apply at 4 pounds active ingredient per acre (a.i./A) for the control of annual grasses.

Bensulide (*Betasan, Lescosan, Betamec*)* is used primarily for the control of annual grasses. Apply at a rate of 10 to 12 pounds a.i./A and irrigate after application. Bensulide can be used in established flower beds and carpet bugle, ivy, pachysandra, and sedum groundcovers. This herbicide is commonly used for preemergence crabgrass control in lawns.

Chloramben (*Ornamental Weeder, Amiben, Garden Weeder, Weedone*)* is used for control of a number of annual broadleaf and grass weeds. Apply at 4 pounds a.i./A to weed-free soil and irrigate following application. Chloramben is registered for use in established flower beds.

DCPA (*Dacthal*)* is available in wettable powder and granular formulations. Apply at 10 to 12 pounds a.i./A to a weed-free area primarily for the control of annual grasses. DCPA has a very extensive list of established flower species on its label. It is also labeled for use on many woody species. In areas without vegetative cover, more than one application per growing season will be necessary.

Dichlobenil (*Barrier, Casoron, Dyclomec, Norosac*)* is available in wettable powder and granular formulations. Apply at 4 to 6 pounds a.i./A to control annual and perennial grasses and many broadleaf weeds. Use only on woody plants listed on the label. Dichlobenil is recommended for use in late fall and winter. If it is applied in warm weather, it should be incorporated into the soil or covered with mulch. This compound can also be used to control some aquatic weeds in nonflowing water.

Diphenamid (*Enide*)* is recommended for annual weed control in flower beds and planting of woody ornamentals. Apply at 8 pounds a.i./A to sandy soils and 12 pounds a.i./A to heavy soils. Effectiveness will be increased with shallow incorporation or irrigation following application. More than one application will be necessary for season-long control.

EPTC (*Eptam*)* is available in emulsifiable concentrate and granular formulations. Apply at 5 pounds a.i./A for control of annual weeds and suppression of certain perennial weeds such as nutsedge and quackgrass. Incorporation is necessary for good control.

*Trade names appear in parentheses.

Isoxaben (*Gallery*)* is recommended for fall and spring application for preemergence control of broadleaf weeds. An application of 1 pound a.i./A should result in season-long or near season-long weed control.

Metolachlor (*Dual, Pennant*)* has recently been labeled for use on a number of woody ornamental species. It will effectively control annual grasses, a number of broadleaf weeds, and nutsedge. Applications of 4 pounds a.i./A will last for one growing season. Pennant is a granular formulation intended for use in ornamentals.

Napropamide (*Devrinol*)* is available in emulsifiable concentrate, wettable powder and granular formulations. It is labeled for use in annual and perennial flower beds, groundcovers, and woody plants. Apply at 4 to 6 pounds a.i./A for control of annual grasses and some broadleaf weeds. Incorporate to a depth of 2 inches or irrigate following application to improve control.

Oryzalin (*Surflan*)* can be used to control annual grasses and some broadleaf weeds in established plantings of groundcovers and woody ornamentals. It does not require incorporation, but it should be irrigated into the soil if there is no rainfall within a week or two of application. Oryzalin (1%) is formulated in combination with oxyfluorfen (2%) to produce the product *Rout*, which is commonly recommended for use in container plant production.

Oxyfluorfen (*Goal*)* can be used as both a preemergence and postemergence herbicide. Its postemergence activity is limited to young broadleaf weeds. Groundsel and chickweed are controlled by this herbicide. The granular formulation is recommended for deciduous plants. Either the EC or granular formulation can be used on conifers. (See oryzalin for information about *Rout*.)

Oxidiazon (*Ronstar or Ornamental Herbicide I*)* is used in new and established plantings of groundcovers and woody ornamental plants. Apply at 4 pounds a.i./A. Two applications may be needed for season-long weed control. It will control a broad spectrum of weed species.

Pedimethalin (Stomp)* is used for the preemergence control of grasses and some broadleaf weeds. It is currently labeled for field applications of coniferous tree plantings. Pendimethalin (1%) is combined with oxyfluorfen (2%) to form the commercial product Ornamental Herbicide 2 (see oxyfluorfen for details). This product is labeled for use in both field- and container-grown nursery crops.

Pronamide (*Kerb*)* should be applied in the fall at 2 pounds a.i./A for the control of winter annuals, chickweed, and quackgrass. It is one of the only selective herbicides that control quackgrass in established landscape plantings.

Simazine (*Princep*)* is available in wettable powder and granular formulations. Spring or fall application at 2 pounds a.i./A to weed-free, woody ornamentals will control a broad spectrum of weeds. Be careful to apply to only labeled species and at recommended rates since simazine will injure a number of ornamental species. This herbicide is also used for weed control on staging area for container-grown plant production.

Trifluralin (*Treflan or Preen*)* is available in emulsifiable concentrate and granular formulations. Apply at 1 pound a.i./A and incorporate into the soil. It is used in flower beds, groundcovers, and woody ornamental plantings. Since it needs to be incorporated, it is not easy to use in thickly established plantings.

POSTEMERGENCE HERBICIDES

Dalapon (*Basfapon, Dowpon M*, and others)* is used for postemergence control of annual and perennial grasses. Apply at 5 pounds a.i./A. Dalapon will provide excellent control of cattails if applied when the plants are small.

Fluaziflop-butyl (*Fusilade 2000, Ornamec*)* is a grass-selective postemergence herbicide effective at controlling a wide range of grass species. It should be applied to young grasses in the 3- to 5-leaf stage.

Glyphosate (*Roundup, Kleenup*)* is a nonselective systemic postemergence herbicide. After being applied to the foliage of weeds, it is translocated into the root system and the entire plant is killed. Even though enough of this herbicide to kill the plant will enter the tissue within hours, it may take 10 days to 2 weeks for the weed to appear completely dead. Keep this herbicide off the foliage of ornamental plants. There is no soil activity, therefore it can be applied over the root systems of herbaceous and woody ornamentals. It can be used to remove grass from around the base of mature trees since it will not injure the trees' bark. However, applicators should avoid spraying glyphosate on the foliage of suckers at the base of trees. Applicators such as rope wicks, wipers, lighting hoes, etc., have been developed for selectively placed glyphosate on weed foliage but not for the foliage of ornamental and crop plants.

*Trade names appear in parentheses.

Oxyfluorfen (*Goal*)* has postemergence as well as preemergence herbicide activity. It will control many broadleaf weeds when they are in the seedling stage. It will not control mature plants postemergence. A combination of oxyfluorfen plus oryzalin is sold as the product *Rout*, which is commonly used for weed control in container plant production.

Paraquat (*Ortho Paraquat QL, Gramoxone*)* is a contact postemergence herbicide. It will give excellent control of annual weeds; however, perennial weeds often grow back from the root system. Apply at 0.5-1.0 pound a.i./A. Since the area to be treated is often less than 1 acre, Table 1 gives a conversion table for using herbicides on small areas where rate per acre is given. Rates per acre are usually given on the label.

Sethoxydim (*Poast*)* is a grass-selective postemergence herbicide labeled for a number of ornamental plants. Grasses are best controlled in the 3- to 5-leaf stage.

HERBACEOUS PLANTINGS

The problematic periods in plantings of annual and perennial bedding plants and groundcovers occur during establishment and then during maintenance of the plantings. As many weeds as possible should be controlled prior to planting.

New bed areas are often developed in locations covered with turf that is full of perennial weeds. Spading or rototilling is not adequate to control perennial weeds. There are two approaches to controlling perennial weeds before planting. The first is to treat the perennial weeds with a systemic postemergence herbicide before preparing the soil in the bed area. The best herbicide for this is glyphosate. If the weed infestation is heavy and there is a significant perennial weed population, use two applications of glyphosate one month apart prior to planting.

Another approach to controlling perennial weeds prior to planting is to fumigate the beds. Methyl bromide, chloropicrin, metham-sodium, and Vorlex (Table 2) are fumigants available for this purpose. Methyl bromide and methyl bromide: chloropicrin combinations are most commonly used for this purpose.

After the bed is prepared, preemergence herbicides may be used either before or after planting, depending on the herbicide used. If the preemergence herbicides are used prior to planting, they should be incorporated into the upper 4 inches of soil. If the preemergence herbicides are applied after planting, they should be incorporated into the soil and irrigated. Mulch before planting since it is easier to plant through a mulch than to place mulch on small plants.

Preemergence herbicides recommended for use in herbaceous plantings are bensulide, chloramben, chlorpropham, DCPA, diphenamid, napropamide, oryzalin, and trifluralin. Other herbicides may be labeled for use, but the aforementioned compounds represent those materials with the most extensive list of herbaceous ornamental plants on their labels.

PLANTINGS OF WOODY LANDSCAPE PLANTS

Beds of new plantings should be cleaned of weeds, treated with a preemergence herbicide, and mulched. This will provide weed control for one season. Future applications of preemergence herbicides can be made in the fall or spring, depending on the herbicide used and the time available. Ideally, a fall treatment for the control of winter annuals followed by a spring application to control summer annuals will give the most satisfactory results.

It should be remembered that no preemergence herbicide will control all species of weeds. A combination of two herbicides controlling different weed species will provide a broader spectrum of weed control. If two preemergence herbicides are used together, use each of them at one-half the rate recommended when they are used alone. Combinations for broad spectrum weed control are simazine + metolachlor, simazine + napropamide, simazine + oryzalin, simazine + DCPA, oryzalin + oxidiazon, oryzalin + isoxaben, metalachlor + isoxaben, pendamethalin + isoxaben, or pendamethalin + oxyfluorfen.

All of the postemergence herbicides mentioned above can be used with care in plantings of woody ornamentals. Glyphosate and paraquat should be kept off the foliage of landscape plants. Paraquat should also be kept off the bark of young trees. When spraying the base of trees with glyphosate, avoid spraying suckers. Combinations of postemergence and preemergence herbicides will control existing weeds as well as weeds that are yet to germinate.

Successful use of herbicides depends upon their proper selection and application. Weed control programs in landscape plantings are only as good as the people who plan, administer, and apply them. Remember, the key to a good weed control program is people and their willingness to keep current with the ever-changing field of herbicide technology.

*Trade names appear in parentheses.

Table 1. Conversion Table for Use of Herbicides on Small Areas When Rate per Acre is Given

Rate of commercial formulations per acre	Approximate rate per 1,000 square feet
Liquid materials	
1 pint	3/4 T.*
1 quart	1 1/2 T.
2 quarts	3 T.
1 gallon	6 T.
Dry materials	
1 pound	2 1/4 tsp.**
2 pounds	4 1/2 tsp.
3 pounds	2 1/4 T.
4 pounds	3 T.
5 pounds	4 T.
10 pounds	1/2 cup
100 pounds	2 1/4 pounds

* Tablespoon.
** Teaspoon.

Table 2. Common and Trade Names of Fumigants for Preplant Bed Preparation

Common name	Trade name
dazomet	Basamid
methyl bromide	Brom-O-Gas, Dowfume, Fumigant-1, Meth-O-Gas, Pestmaster, Terr-O-Gas
metham-sodium	Best Vapam Soil Fumigant, Science Vapam, Vapam, VPM
chloropicrin	Chlor-O-Pic, Pic-clor, Tri-clor, Larvacide
methylisothiocynanate + dichloropentene-dichloropropane	Vorlex, Di-Tapex
methyl bromide + chloropicrin	Dowfume MC-33, Dowfume MC-2, many more formulations

ORNAMENTAL HERBICIDE REGISTRATIONS

	(PPI)			(PRE)																			(POST*)					
	EPTAM	LASSO	TREFLAN	BETASAN	CASORON	CHIPCO RONSTAR	DACTHAL	DEVRINOL	DUAL	ENIDE	GALLERY	GOAL	KERB	LASSO	OH 1	OH 2	OR. WEEDER	PRINCEP	ROUT	STOMP	SURFLAN	TREFLAN	FUSILADE	GOAL	KERB	PARAQUAT	POAST	ROUNDUP
Abelia spp.				F			F	X			X										X							
Abelia grandiflora				F		C	F	X								X					X							
Abies spp.	F						F	X			X		F										F	F	F	F	F	F
Abies balsamea	F		F				F	X					F					F		F	F	F	F			F		F
Abies fraseri	F						F	X		S		Z	F					F		F	F		F	Z		F	F	F
Acer spp.	F				F		F	F	X	F	F												F					F
Acer ginnala	F				F	F	F	F	X	F													F					F
Acer palmatum	F				F		F	F	X	F													F					F
Acer plantanoides	F		F		F		F	F	X	F												F	F					F
Acer rubrum	F		F		F		F	F	X	F							F					F	F				F	F
Acer saccharinum	F		F		F		F	F	X	F												F	F				F	F
Acer saccharum	F		F		F		F	F	X	F												F	F					F
Ajuga spp.	F			F				F															F					
Ajuga reptans	F			F		F		F															F				F	
Berberis spp.	F				F	X	F		X		X							F					F				F	
Berberis thungergii	F		F		F	X	F		X	F	F							F	X		X	F	F					F
Betula spp.					F		F			F													F				F	
Betula nigra					F		F			F													F				F	
Betula papyrifera					F	F	F			F													F					
Betula pendula			F		F		F			F												F	F				F	
Buxus spp.	F			F	F	C	F	X	X		F					X							F					F
Buxus microphylla	F		F	F	F	C	F	X	X						X	X			X		X	F	F					F
Buxux sempervirens			F	F	F	C	F	X	X						X	X					X	F	F				F	F
Carya spp. (Hickory)					F												F											
Carya illinoiensis					F			F		F	F																F	
Castanea spp.							F																					
Castanea mollissima			F				F															F						
Cedrus spp.								X			F																	
Cedrus deodora								X																				
Cercis candadensis			F				F			F												F	F					
Chaenomeles japonica					F																		F					
Chamaecyparis spp.	F										X										X							
Chamaecyparis obtusa	F															X					X							
Chamaecyparis thyoides	F									F											X							
Cornus spp.	F	F			F		F				F			F		X	F	F					F				F	
Cornus florida	F	F	F		F	F	F			F				F		X	F	F					F				F	
Cornus sericea (C. stolonifera)	F	F			F	X	F		X					F		X	F	F					F				F	
Cortaderia selloana																												
Cotoneaster spp.		F			F	X	F		X	F	X						F	F					F				F	
Cotoneaster apiculata		F	F		F	X	F		X	F					X	X	F	F			X	F	F				F	
Cotoneaster dammeri		F			F	X	F		X	F							F	F	X		X		F				F	
Cotoneaster horizontalis		F			F	X	F		X	F							F	F			X		F					
Cotoneaster microphyllus		F			F	X	F		X	F							F	F			X		F					
Cotoneaster zabelii		F	F		F	X	F		X	F							F	F					F					
Crataegus spp.							F	F														F						
Deutzia spp.			F		F		F															F						
Elaeagnus spp.					F		F			F								F										
Elaeagnus angustifolia					F	F	F			F								F									F	
Elaeagnus pungens			F		F		F			F								F				F						
Euonymus spp.	F	F			F	X	F	X	X	F				F		X	F					F					F	F

ORNAMENTAL HERBICIDE REGISTRATIONS (Continued)

	(PPI)			(									PRE										)	(		POST*			)
	EPTAM	LASSO	TREFLAN	BETASAN	CASORON	CHIPCO RONSTAR	DACTHAL	DEVRINOL	DUAL	ENIDE	GALLERY	GOAL	KERB	LASSO	OH 1	OH 2	OR. WEEDER	PRINCEP	ROUT	STOMP	SURFLAN	TREFLAN	FUSILADE	GOAL	KERB	PARAQUAT	POAST	ROUNDUP
Euonymus alatus	F	F			F	X	F	X	X	F				F			F		X		X	F	F				F	F
Euonymus fortunei	F	F	F		F	X	F	X	X	F				F	X	X	F		X		X	F	F					F
Fagus grandifolia										F													F					
Forsythia spp.			F		F	X	F		X	F			F									F	F		F		F	
Forsythia intermedia			F		F	X	F		X	F	F		F			X					X	F	F		F			
Fraxinus spp.					F		F	F															F			F		
Fraxinus americana			F		F		F	F		F							F					F	F			F	F	
Fraxinus pennsylvanica					F		F	F															F			F	F	
Ginkgo biloba						C															X							
Gleditsia triacanthos			F		F		F	F										F				F					F	
Hedera helix	F		F	F	F	X	F	X	X	F	X						F				X		F				F	
Hibiscus syriacus								F		F	X								X		X							
Hosta spp.											X																	
Hydrangea spp.							F			F						X												
Hypericum spp.	F		F	F				F		F									X		X							
Iberis sempervirens				F			F												X									
Ilex spp.		X		F			F	X		F	X		F		X		F	F					F		F			F
Ilex aquifolium		X		F	F	X	F	X		F			F				F	F			F		F		F			F
Ilex cornuta		X		F	F	X	F	X		F			F		X	X	F	F	X		X	F	F		F		F	F
Ilex crenata	F	X	F	F		X	F	X	X	F			F		X	X	F	F			X		F		F		F	F
Ilex glabra		X		F	F		F	X		F			F				F	F					F		F			F
Ilex opaca	F	X		F	F		F	X	X	F			F		X		F	F					F		F			F
Juglans spp.							F	F			F															F		
Juglans nigra			F				F	F		Z	F							F				F				F	F	
Juniperus spp.	F	X		F	F		F	X		F	X		F	X			F	F			X		F	C	F		F	
Juniperus chinensis	F	X	F	F	F	X	F	X		F		C	F	X	X	X	F	F	X		X	F	F	C	F		F	
Juniperus conferta	F	X	F	F	F	C	F	X	X	F			F	X			F	F	X		X	F	F		F		F	
Juniperus horizontalis	F	X		F	F	X	F	X	X	F		C	F	X	X	X	F	F	X		X		F	C	F		F	
Juniperus procumbens	F	X		F	F	C	F	X	X	F			F	X			F	F			X		F		F			
Juniperus virginiana	F	X	F	F	F		F	X		F			F	X			F	F			X	F	F		F		F	
Kalmia spp.							F		X	F																		
Kalmia latifolia			F		F		F		X												X	F						
Koelreuteria paniculata					F	F																						
Kolkwitzia amabilis						F				F																		
Lagerstroemia indica				F		C													X		X		F					
Leucothoe spp.	F				F	C			X																			
Leucothoe axillaris	F					C			X												X							
Ligustrum spp.				F	F		F	X	X	F													F			F		F
Ligustrum ovalifolium			F	F	F	X	F	X	X	F												F	F					F
Liquidambar styraciflua			F				F			F	F										X	F	F				F	
Liorodendron tulipifera			F		F		F			F												F	F				F	
Liriope spp.			F					X			X										X		F				F	
Lonicera spp. (Xylosema)			F	F	F	X	F		X	F						X					X	F						
Lonicera fragrantissima			F	F	F	X	F		X	F								F			X							
Magnolia spp.	F				F		F										F						F					F
Magnolia grandiflora	F				F	C	F										F				X						F	F
Mahonia spp.										F	F							F			X							
Malus spp.		F	F		F			F	X	F											F	F	F			F	F	F
Malus floribunda		F	F		F	F	F	F	X	F				F							F		F			F	F	F
Malus pumila		F	F		F			F	X	F								F			F		F			F		F
Nyssa sylvatica			F																			F						
Osmanthus spp.					F	C			X																			

ORNAMENTAL HERBICIDE REGISTRATIONS (Continued)

	(PPI)			(PRE																	)	(POST*					)
	EPTAM	LASSO	TREFLAN	BETASAN	CASORON	CHIPCO RONSTAR	DACTHAL	DEVRINOL	DUAL	ENIDE	GALLERY	GOAL	KERB	LASSO	OH 1	OH 2	OR. WEEDER	PRINCEP	ROUT	STOMP	SURFLAN	TREFLAN	FUSILADE	GOAL	KERB	PARAQUAT	POAST	ROUNDUP
Osmanthus heterophyllus									X												X							
Pachysandra terminalis	F			F			F	F	X		X																F	
Parthenocissus tricuspidata							F																				F	
Philadelphus spp.			F		F		F			F												F						
Picea spp.	F						F	F			X												F				F	
Picea abies	F		F			F	F	F		S		W						F	X		F	F	F	W			F	F
Picea glauca	F		F				F	F		S					X			F	X		F	F	F				F	F
Picea pungens	F		F				F	F			F	W			X			F		F	X	F	F	W			F	F
Pieris spp.	F					C	F		X								F	F										
Pinus spp.	F						F	X			F		F				F						F		F	F		F
Pinus mugo	F						F	X				C	F		X		F	F	X	X			F	C	F	F	F	F
Pinus nigra	F		F			X	F	X		S		C	F				F			F	F	F	F	C	F	F	F	F
Pinus resinosa	F		F			F	F	X					F				F	F					F		F	F		F
Pinus strobus	F		F			F	F	X		S		W	F				F	F	X		X	F	F	W	F	F	F	F
Pinus sylvestris	F		F			X	F	X		S		C	F				F	F		F	F	F	F	C	F	F	F	F
Pinus thunbergii	F		F			X	F	X					F			X	F		X		X	F	F		F	F	F	F
Pinus virginiana	F						F	X				W	F		X	X	F					F	F	W	F	F	F	F
Platanus spp.							F				F																	
Platanus acerifolia		F	F				F															F						
Platanus occidentalis			F				F			F												F					F	
Platycladus orientalis (Thuja)							F		X			C			X		F	F			X		F	C				
Populus spp.					F		F	F																				
Populus deltoides			F		F		F	F		F												F						
Prunus spp. (peach & cherry)			F					F		F	F				F							F	F			F	F	
Prunus spp. (plum)			F					F		F											F		F			F	F	
Prunus caroliniana			F					F		F											F	F	F			F		
Prunus cerasifera								F		F											F		F			F		
Prunus laurocerasus					F			F		F											F		F			F		
Prunus persica								F		F											F		F			F		
Prunus sargentii								F		F											F		F			F		
Prunus serrulata								F		F											F		F			F		
Prunus subhirtella pendulata								F		F											F		F			F		
Prunus yedoensis								F		F											F		F			F		
Pseudotsuga menziesii/ taxifolia			F				F	X		S		Z	F					F			F	F	F	Z	F		F	F
Pyracantha spp.			F	F	F	C		X	X	F	X										X	F	F					
Pyracantha coccinea				F	F	C		X	X	F					X						X		F					
Pyrus spp. (pear)					F			F		F	F										F		F				F	
Pyrus calleryana 'Bradford'					F			F													F		F					
Quercus spp.	F				F	C	F			F	F				X								F			F	F	F
Quercus alba	F				F	C	F			F													F			F		F
Quercus coccinea	F		F		F	C	F			F												F	F			F		F
Quercus palustris	F		F			C	F			F												F	F			F		F
Quercus phellos	F					C	F			F													F			F	F	F
Quercus rubra	F		F			X	F			F							F	F				F	F			F		F
Rhododendron spp. (azalea)				F			F	X		F	X		F			X	F	X			X		F		F		F	F
Rhododendron spp. (rhodo.)	F				F		F	X	X	F	X		F		X	X	F				X		F		F		F	F

ORNAMENTAL HERBICIDE REGISTRATIONS (Continued)

	(PPI)			(						PRE											)	(		POST*			)
	EPTAM	LASSO	TREFLAN	BETASAN	CASORON	CHIPCO RONSTAR	DACTHAL	DEVRINOL	DUAL	ENIDE	GALLERY	GOAL	KERB	LASSO	OH 1	OH 2	OR. WEEDER	PRINCEP	ROUT	STOMP	SURFLAN	TREFLAN	FUSILADE	GOAL	KERB	PARAQUAT	POAST	ROUNDUP
Rhododendron, Azalea hybrids-Exbury, Satsuki, Glen Dale				F			F	X		F			F			X	F		X		X		F		F			F
Rhododendron indica			F	F		X	F	X		F			F			X	F				X	F	F		F		F	F
Rhododendron molle				F	F		F	X		F			F			X	F				X		F		F		F	F
Rhododendron obtusum			F	F	F	X	F	X		F			F		X	X	F		X		X	F	F		F		F	F
Rosa spp.	F		F		F	X	F	X	X	Z	F										X	F						
Salix spp.			F		F		F			F	F											F	F				F	
Sedum spp.	F			F		F	F														X							
Spiraea spp.					F		F		X	F					X	X	F						F				F	
Spiraea vanhouttei			F		F		F		X	F					X	X	F					F	F				F	
Syringa spp.	F				F		F				F																	F
Syringa persica	F				F	F	F																					F
Syringa vulgaris	F		F		F		F			F											X	F						F
Taxodium distichum			F							Z												F						
Taxus spp.	F	F			F		F	F	X		X	C	F	F		X	F	F					F	C	F			F
Taxus canadensis	F	F			F		F	F	X	F		C	F				F	F					F	C				F
Taxus cuspidata	F	F	F		F		F	F	X			C	F			X	F	F			X	F	F	C			F	F
Taxus media	F	F	F		F	F	F	F	X			C	F				F	F				F	F	C				F
Thuja spp.					F	C	F	C	X		X	C				X	F	F			X		F	C		F		F
Thuja occidentalis			F		F	F	F	C	X	Z		C				X	F	F	X				F	C		F	F	F
Tilia spp.	F				F						F																F	
Tsuga spp.	F							F									F	F					F					F
Tsuga candensis	F		F			F		F		Z		S					F	F				F	F	S			F	F
Tsuga caroliniana	F							F									F	F					F					F
Ulmus spp.					F		F				F							F					F			F		
Ulmus americana					F		F											F					F			F		
Vaccinium spp.										F	F																	
Viburnum spp.	F					X	F		X	F	F					X	F		X				F					
Viburnum suspensum	F		F			X	F		X	F							F				X	F	F					
Viburnum trilobum																										F		
Viburnum wrightii	F		F			X	F		X	F							F					F	F					
Vinca spp.	F		F	F				F	X	F																		
Vinca minor	F		F	F		X		F	X	F											X		F				F	
Weigela spp.			F		F		F		X	F	X								X		X	F						
Wisteria spp.																												
Yucca spp.																												
Yucca filamentosa															X													
Zelkova serrata																												

*Many chemicals are labeled for directed applications only; check labels for specific restrictions.

KEY TO WEED CONTROL:
- F=field
- D=dormant stock only
- Y=field-dormant stock
- W=field + container + seedbed
- C=container
- S=seedbed
- X=field + container
- Z=field + seedbed

INSECT PEST MANAGEMENT RECOMMENDATIONS FOR TREE AND SHRUB INSECTS

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
Aphids (NHE-47)	acephate 75% S	1/2	When aphids are numerous. Spray with high pressure and thoroughly cover the foliage.
	malathion 50-57%E,	1	
	diazinon 4E, 4E, 25%E, 50W	1	
Ash borer (NHE-145)	chlorpyrifos 2E, 4E, 50W	1	Apply in early June and repeat 4 weeks later.
Bagworm (NHE-16)	malathion 50-57%E, 25W	1	Spray foliage thoroughly about June 15 while worms are still small and before extensive feeding has occurred.
	tempo 2E	0.015-0.03	
	chlorpyrifos 2E, 4E, 50W,	1/2	
	trichlorfon	1	
	Bacillus thuringiensis	follow label directions	
Birch leaf miner	acephate 75%S	1 1/3	Spray foliage thoroughly when miners first appear. Repeat 10 to 12 days later.
	dimethoate 2E	1/4	
	chlorpyrifos 2E, 4E, 50W	1	
Black vine weevil	acephate 75%S	1	Spray foliage thoroughly in mid-May when adults are on foliage. Allow spray to run off onto soil under shrubs. Repeat twice at 2-week intervals.
	bendiocarb 76W	1 1/4	
	tempo 2E	0.03	
Bronze birch borer (NHE-143)	dimethoate 2E, 25W	1/2	For dimethoate - spray bark of trunk and limbs in late May and repeat 3 weeks later or apply a 6-inch wide band of concentrate on trunk as a single treatment.
	chlorpyrifos	1	For chlorpyrifos - apply to trunk and limbs in mid-May, and repeat twice in 2-week intervals.
Cankerworm (NHE-95)	acephate 75%S	1/2	Spray when worms are still small as leaf buds are opening in spring.
	malathion 50-57%E	1	
	carbaryl 80%S, 50W	1	
	Bacillus thuringiensis	follow label directions	

[a] Treatment dates are listed for central Illinois. In southern Illinois apply 2 weeks earlier and in northern Illinois 2 weeks later.

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
Cicada (NHE-113)	carbaryl 80%S, 50W tempo 2E	1 0.03	Spray foliage when egg-laying begins. Repeat every 5 days while adult cicadas are present.
Cooley spruce gall aphid (NHE-80, 81)	acephate 75% malathion 50-57% E diazinon 4E, 25% E, 50W	2/3 1 1	Apply in late September or in spring just after buds break.
Cottony maple scale (NHE-144)	acephate 75%S malathion 50-57%E	2/3 1	Spray heavily infested foliage in July after crawlers have hatched and are active, and repeat 10 days later.
	superior oil	2 gallons	Apply in spring before leaf emergence. Do not use on Japanese or sugar maple.
Dogwood borer	chlorpyrifos 2E, 4E, 50W	1	Apply in mid-May and repeat 4 weeks later.
Eastern spruce gall aphid	acephate 75% malathion 50-57% E	2/3 1	Apply in late Setpember or in spring just after the buds break.
Eastern tent caterpillar	acephate 75%S malathion 50-57%E *Bacillus thuringiensis* chlorpyrifos 2E, 4E, 50W tempo 2E	1/2 1 follow label directions 1 0.015-0.03	Spray areas of tree where nests first appear in early spring. Remove small nests from trees or prune out webs and destroy them.
Elm bark beetles	methoxychlor		Contact Center for Biodiversity, Illinois Natural History Survey 607 East Peabody Drive, Champaign, Illinois 61820, for information on Dutch elm disease control.
Elm leaf beetle (NHE-82)	carbaryl 80%S, 50W acephate 75%S *Bacillus thuringiensis* 'san diego'	1 1/2 follow label directions	Apply when damage first appears, usually late May and again in late July-early August.
Euonymous scale (NHE-100, 114, 146)	acephate 75%S dimethoate 2E, 25W malathion 50-57%E diazinon 4E, 25%E, 50W	2/3 1 1 1	Spray in early June when crawlers are active. Make four applications 10 to 12 days apart.

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
European elm scale (NHE-100, 114, 146)	malathion 50-57%E	1	Apply to infested trees in early spring when first leaves appear.
European pine sawfly	carbaryl 80%S, 50W	1	Spray when worms are small and feeding on the needles.
	chlorpyrifos 2E, 4E, 50W	1	
	diazinon 4E, 25%E, 50W	1	
European pine shoot moth (NHE-83)	dimethoate 2E	1	Spray ends of branches thoroughly in late June before larvae enter the growing shoot.
Fall webworm	acephate 75%S	1/2	Spray nests or webbed areas in trees in late summer. Do not apply acephate to crabapple. If webs are small, prune out and destroy.
	carbaryl 80%S, 50W	1	
	malathion 50-57%E	1	
	Bacillus thuringiensis	follow label directions	
	chlorpyrifos 2E, 4E, 50W	1	
Flat-headed apple tree borer	chlorpyrifos 2E, 4E, 50W	1	Spray in late May and repeat after 3 weeks. Keep trees in vigorous growing condition. Wrap trunks of new set trees with paper or burlap.
Fletcher scale (NHE-100, 114, 146)	malathion 50-57%EC	1	Apply in early April and repeat in early June.
Gouty oak gall	...	...	Prune out infested branches and destroy.
Hackberry psyllids (NHE-80,81)	malathion 50-57%E	1	Apply in late May. This insect rarely damages trees. Control is usually not necessary.
	diazinon 4E, 25%E, 50W	1	
Hawthorn leaf miner	acephate 75%S	2/3	Treat in early May or when first sign of leaf-browning appears.
Hawthorn mealy bug	malathion 50-57%E,	1	Apply when insects are numerous.
	diazinon 4E, 25%E, 50W	1	
	dimethoate 2E	1/2	

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
Holly leaf miner	dimethoate 2E acephate 75%S	1/2 1/2	Spray foliage in late May or early June when leaf miners first appear.
Honeysuckle aphid	acephate 75%S oxydemeton-methyl 25%E	1/2 3/4	Spray at first sign of damage. Repeat 4 weeks later.
Lacebug	acephate 75%S carbaryl 80%S, 50W tempo 2E	1/2 1 0.015-0.03	Spray when bugs are numerous.
Leaf crumpler	malathion 50-57%E diazinon 4E, 25%E, 50W	1 1	Spray in late May and again in late August.
Leafhoppers	carbaryl 50W, 80%S tempo 2E permethrin 3.2 E	1 0.015-0.03 0.1-0.2	Spray when hoppers are numerous on foliage. Permethrin is for use on nursery stock only.
Lecanium scale (NHE-146)	acephate 75%S diazinon 4E, 25%E, 50W malathion 50-57%E	2/3 1 1	Apply to infested trees in mid-June when crawlers are active and repeat 2 weeks later.
Lilac borer (NHE-145)	chlorpyrifos 2E, 4E, 50W	1	Apply in mid-May and repeat 4 weeks later.
Locust borer	chlorpyrifos 2E, 4E, 50W	1	Apply in late August and again in mid-September.
Locust mite	fenbutatin-oxide, 50W dicofol	1/2 1/3	Apply in early spring just before leaves appear. Repeat spray 2 weeks later.
Magnolia scale (NHE-100, 114, 146)	malathion 50-57%E diazinon 4E, 25%E, 50W	1 1	Treat in late September or early spring when buds are opening.
Maple bladder gall mite (NHE-80, 81)	...	...	No effective control available.
Mimosa webworm (NHE-109)	acephate 75%S malathion 50-57%E *Bacillus thuringiensis* chlorpyrifos 2E, 4E, 50W	1/2 1 follow label directions 1	Spray in early July or when webs first appear. Repeat in early August for second generation.

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
Mountain ash borer	chlorpyrifos 2E, 4E, 50W	1	Treat in early June and repeat 4 weeks later.
Nantucket pine tip moth (NHE-83)	acephate75%S	1/2	Spray ends of branches in mid-April and late June before the larvae enter the growing shoot.
	dimethoate 2E	1	
Oak kermes	acephate	2/3	Apply in early July when crawlers appear on foliage.
	malathion 50-57% E	1	
	diazinon 4E, 25%E, 50W	1	
Obscure scale (NHE-100, 114, 146)	superior oil	2 gallons	Apply oil in late October or in early spring just prior to leaf emergence. Apply others in early to mid-July when crawlers are active.
	malathion 50-57%E	1	
	chlorpyrifos 2E, 4E, 50W	1	
Oystershell scale (NHE-100, 114, 146)	malathion 50-57%E	1	Apply in early June when crawlers are active and repeat 10 to 12 days later. Repeat sprays again in early August in central and southern Illinois.
	chlorpyrifos 2E, 4E, 50W	1	
Peach tree borer (NHE-112)	chlorpyrifos 2E, 4E, 50W	1	Thoroughly spray the bark of trunk and limbs in mid-June and repeat 4 weeks later. Keep trees vigorous and avoid wounds or mechanical injury of the trunk and upper branches.
Periodical cicada (NHE-113)	carbaryl 80%S, 50W	1	Spray in June when adults are laying eggs.
	tempo 2E	0.03	
Pine bark aphid	malathion 50-57%E	1	Spray when aphids are present, usually in May and later. Add spreader.
	diazinon 4E, 25%E, 50W	1	
	acephate 75%S	1/3	
	dimethoate 2E	1/2	
Pine needle scale (NHE-100, 114, 146)	acephate 75%S	1/2	Apply spray in late May when crawlers are active if trees are infested.
	malathion 50-57%E	1	
	diazinon 4E, 25%E, 50W	1	
	chlorpyrifos 2E, 4E, 50W	1	

Insect	Insecticide	Lb. of active ingredient per 100 gal. of water	Timing of application[a]
San Jose scale (NHE-100, 114, 146)	superior oil	2 gallons	Apply to bark of trunk and limbs in spring prior to leaf emergence.
Spider mites (NHE-58)	fenbutatin-oxide 50W	1/2	Spray when mites are numerous, usually mid-summer. Concentrate spray on the undersides of the foliage.
	dienochlor	1/3	
	dicofol 35W	1/3	
Spruce spider mite	dimethoate 2E	1/2	Spray when mites are numerous, usually in early spring. Thorough coverage of foliage is important.
	dienochlor	1/3	
Spittlebug (NHE-7)			No chemical control is necessary.
Taxus mealybug (NHE-7)	acephate 75%S	1/2	Spray foliage with force when insects are present. Repeat 2 weeks later.
	dimethoate 2E	1/2	
Thrips	malathion 50-57%E	1	Spray privet when thrips are numerous.
	acephate 75%S	1/2	
Tuliptree scale	superior oil	2 gallons	Apply oil in late spring before leaves emerge. Apply malathion in mid-August.
	malathion 50-57%E	1	
Virburnum borer	chlorpyrifos 2E, 4E, 50W	1	Apply to trunks in June, be sure to treat bark at and just below soil surface; repeat in 4 weeks.
White-marked tussock moth	malathion 50-57%E	1	Treat in June when worms are small.
	carbaryl 80%S, 50W	1	
	Bacillus thuringiensis	follow label directions	
Yellow-necked caterpillar	malathion 50-57%E	1	Spray foliage when caterpillars are small, usually in late July.
	acephate 75%S	1/2	
	chlorpyrifos 2E, 4E, 50W	1	
	Bacillus thuringiensis	follow label directions	
Zimmerman pine moth	dimethoate 2E	1	Spray bark and foliage either in April for control of larvae or mid-August for control of adults and eggs.
	chlorpyrifos 2E, 4E, 50W	1	

INSECTICIDE NAMES

Common name	Trade names	Common name	Trade names
acephate[a]	Orthene	dienochlor	Pentac
Bacillus thuringiensis	Dipel, Thuricide	dimethoate[d]	Cygon, De-Fend
Bacillus thuringiensis 'san diego'	M-One	fenbutatin-oxide	Vendex
bendiocarb	Turcam, Dicarb	isofenphos	Oftanol
carbaryl[b]	Sevin	malathion[e]	Cythion
chlorpyrifos	Dursban	oxydemeton-methyl	Metasystox-R
cyfluthrin	Tempo	permethrin	Pounce, Ambush
diazinon[c]	Spectracide, diazinon	superior oil[f]	many brands
dicofol	Kelthane	trichlorfon	Dylox, Proxol

[a] Do not use on sugar or Japanese maple, American elm, flowering crab, redbud, cottonwood, or Lombardy poplar.
[b] Do not use on Boston ivy.
[c] Do not use on ferns or hibiscus.
[d] Do not use on chrysanthemums.
[e] Do not use on canaert red cedar.
[f] Do not use on conifers, ferns, sugar maple, or Japanese maple.

Home Fruit Pest Control

PEST CONTROL IS NECESSARY TO GROW TOP-QUALITY fruit. Diseases, insects, mites, birds, and rodents attack all types of fruits grown in home plantings.

Cultural practices such as pruning, fertilizing, planting, and fruit thinning are important pest control practices discussed in Circular 1013, *Growing Tree Fruits in the Home Orchard,* Circular 935, *Growing Small Fruits in the Home Garden,* and Circular 1144, *Controlling Weeds in Home Fruit Plantings.* These circulars are available from your county Extension office or from the Office of Publications, College of Agriculture, University of Illinois at Urbana-Champaign, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801.

Cultural Tips for Tree Fruits

Prune fruit trees each year to keep them short and well shaped. Well-pruned trees are easier to spray. Destroy (burn) all prunings including dead and diseased branches.

Keep the grass under and around trees mowed. Grass harbors mites, aphids, and other injurious insects.

During the spray season, pick up and destroy or bury any fallen fruit damaged by insects or diseases. In the fall, rake up all fallen leaves and fruit. Then burn, compost, or bury them.

Cultural Tips for Small Fruits

Good cultural practices help prevent and control insect and disease problems. See the notes under the spray schedule for each small fruit species for specific cultural tips.

Spraying Tips

Good spray coverage is essential for adequate pest control. Thoroughly wet the undersides of the leaves, the fruit, the limbs, and the trunk, as well as the upper sides of the leaves. Because insect and disease control are most difficult in the upper portions of the tree, direct two-thirds of the spray into the top half of the tree. Spray until the tree begins to drip.

If the leaves or fruit are waxy, the spray may stay in drops instead of spreading over the surface. Add one teaspoonful of liquid household detergent per gallon of spray after filling the sprayer to help spread the spray evenly.

Don't skip sprays — insects and diseases do not take vacations. Depending on the crop, sprays must be applied on a 7- to 14-day schedule.

To have a good spray program, always observe the following suggestions:

1. Do not use herbicides (weed-killers) in sprayers to be used for insect and disease control.
2. Spray before rains for disease control and allow sufficient time for the spray to dry. Disease-causing organisms infect plants in as few as 6 to 8 hours when plants are wet.
3. Make up a fresh spray mix for each application. Discard leftover spray; never save it for a future application. Always use clean water.
4. Stir the spray mixture or shake the sprayer frequently while spraying so that the chemicals will not settle out.
5. Wash out the sprayer as soon as you stop spraying. Do not wait until the next day; such a delay may result in a clogged sprayer.
6. During bloom, apply fungicide sprays when they are suggested, but leave out the insecticides. Honeybees and certain other pollinating insects are essential for many kinds of fruit to develop. If insecticides are applied during bloom, helpful insects will be killed, and you will end up with little or no fruit.

Tank Mix and Multipurpose Mix

Wettable powders (WP) are preferred over liquid concentrates (EC) because liquid concentrates are more likely to cause injury to leaves and fruit.

Wettable powders must be thoroughly dispersed in water, or they will clog the spray nozzle. One method of mixing sprays in compressed-air and other types of sprayers without agitators is as follows: measure the pesticides, place them in the tank, and then use a hose to fill the sprayer. Use the hose nozzle to thoroughly mix the spray as the tank is filled. While spraying, shake the tank frequently to keep the materials dispersed.

Another mixing method is to measure the pesticides into a small can or jar, add a small amount of water, and stir into a smooth, thin slurry. Then wash the slurry into the spray tank and fill to the desired level.

For sprayers equipped with an agitator, fill the tank one-third full of water, start the engine and the agitator, then sift in the wettable powders, and finish filling the sprayer.

Using a ready-to-use multipurpose mix (Table 1) is sometimes more convenient than mixing separate materials in the tank. Many multipurpose fruit spray mixes are available. These mixes usually contain one or two insecticides, one or two fungicides, and sometimes a miticide. A widely sold multipurpose fruit spray contains methoxychlor, malathion, and captan. The individual components may be purchased in 1- to 5-pound packages and mixed at home just before spraying.

Imidan or Diazinon may be substituted for the combination of malathion and methoxychlor. Imidan

Table 1. Multipurpose Spray Mix

Materials	Amount of spray mix to add to water to make 1 gallon	5 gallons	10 gallons
Methoxychlor	2 tbsp.	1 cup	2 cups
plus Malathion, 25% WP	2 tbsp.	¾ cup	1½ cups
plus captan, 50% WP	1½ tbsp.	¾ cup	1½ cups
or ferbam, 76% WP	2 tbsp.	¾ cup	1½ cups

is labeled only for tree fruits and grapes. Other pesticides not mentioned in this circular are registered for use on certain fruits and may be substituted at certain times in the schedules.

The initial investment for a multipurpose spray is considerably less than buying each material separately, but over a period of years the cost usually is greater for three reasons. First, the cost per pound of material usually is greater. Second, not all of the ingredients in the multipurpose spray are needed for some applications. And third, for some fruits less costly materials are often just as effective. Mixing the separate chemicals also allows variations in the mixture to suit the conditions and the plant being sprayed.

Most spray chemicals will retain their effectiveness for three or more years if stored in a dry place. Malathion, which has a disagreeable odor, should be stored in a closed metal container.

Insecticides, miticides, and fungicides are sold under a number of trade (or product) names. To avoid confusion, both common (or generic) and trade names are used in this circular (Table 2). The common name of the pesticide is always shown on the label as the active ingredient.

Table 2. Common and Trade Names of Pesticides

Common name	Trade name
Insecticides and miticides	
carbaryl	Sevin, 50% WP
diazinon	Diazinon, 50% WP
malathion	Malathion, 25% WP and 57% EC
methoxychlor	Methoxychlor, 50% WP
Fungicides	
benomyl	Benlate, 50% WP
captan	Captan, 50% WP
dinocap	Karathane, Dinocap, 19.5% WP
ferbam	Carbamate, Ferbam, 76% WP
sulfur, wettable	Many names are used.

A common problem in spraying is knowing how much spray to apply per tree. Table 3 should serve as a guide depending on tree height, width (spread), and growth stage.

Spray Schedules

The amounts given in the following spray schedules (Tables 4-11) are in level teaspoons (tsp.), level tablespoons (tbsp.), and level or partial cups. One level cup equals 16 level tablespoons. The suggested amounts are adequate for control. Do not use more pesticide than label rates. Excessive concentration of spray materials may cause injury to the foliage and fruit, and an insufficient concentration will not control the target pest or pests.

Table 3. Approximate Amount of Spray Required for Fruit Trees of Different Sizes

Height in feet	Spread in feet	Gallons per tree per application[a]
4	3	up to ½
5 to 8	3 to 6	¼ to 1
8 to 10	4 to 8	½ to 2
10 to 15	8 to 15	1 to 3
15 to 20	15 to 25	2 to 6

[a] Use the greater amounts for trees in full foliage.

Preventing Mouse Damage

Mice are serious pests of apple trees and sometimes other fruit trees. They eat bark from the main roots and trunk near and below the ground line. Both young and old trees may be damaged. Mouse injury may occur at any time during the year but is usually more serious in late fall, winter, and early spring when other food is scarce.

Natural predators such as cats, hawks, owls, and foxes will greatly reduce the mouse population if protective cover is eliminated. Mow the grass closely under the trees and throughout the orchard. Hoe out all grass and weeds within one foot of the trunk, leaving the ground bare.

Mulches are advantageous for fruit trees, but they may harbor mice. In autumn pull the mulch away from the trunk, leaving one foot of bare ground between the mulch and the trunk.

Mouse traps and anticoagulant baits (for example, Warfarin) may be used. A repellent on the trunk near the ground line will help protect trees from mouse damage. Use a commercially prepared repellent containing thiram, or use the mixture mentioned below for repelling rabbits. Spray or paint the lower trunk in late November and again in February.

A gravel collar around the tree trunk discourages mice and helps control grass and weeds. The collar should be 6 to 8 inches deep and about 2 feet in diameter. The gravel must remain loose to prevent damage to the trunk (see picture).

Preventing Rabbit Damage

In fall, winter, and early spring when food is scarce, rabbits may eat the bark from the trunk and lower limbs of young fruit trees. They also eat the bark from blackberry and raspberry bushes and eat buds on young blueberry plants. Rabbits seldom cause much damage to older fruit trees and older blueberry plants.

Mechanical barriers prevent rabbit damage effectively unless deep snows occur. For young trees, use a circular metal guard 18 inches tall and 6 inches in diameter made from an 18-inch-square piece of hardware cloth (see picture). Or wrap the trunk and lower branches with several layers of newspaper in early November and remove the papers in April.

The most practical mechanical barrier for protecting blackberry, raspberry, and young blueberry plants against rabbits is an 18- to 24-inch-high chicken wire fence.

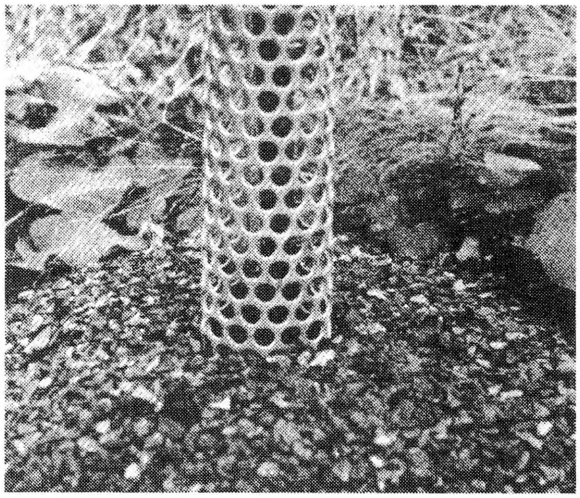
Commercially prepared repellents containing thiram are effective against rabbits, or you can prepare a thiram mixture using a liquid suspension (Gustafson 42-S) 1 part, combined with white latex paint (1 or 2 parts), and water (8 parts).

In October or November paint or spray the parts of plants that need protection from rabbits.

Preventing Bird Damage

Birds are especially destructive pests of blueberries and cherries, and they frequently damage other fruits. Covering the fruit plant with netting just before the fruit ripens is the only practical method of protecting the fruit. Picking fruit promptly as it ripens will reduce losses.

Aluminum pie pans and other reflecting objects hung in fruit plants provide some protection until the birds become adjusted to their presence.



Young apple tree with a metal guard and a gravel collar.

Table 4. Spray Schedule for Apples, Crabapples, Pears, and Quinces

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	Dormant; *before* buds swell, *not later.*	Plant spray oil	5	3	Spray only when the temperature will not go below 33°F for 24 hours.
2	When green tissue is ½ inch out of bud *and again* when fruit buds show color (or turn pink).	Captan *plus* Diazinon OR multipurpose fruit spray *plus* sulfur (if needed)	1½ 1 1	1 ¾ ¾	Add 5 tablespoons of wettable sulfur per gallon or 1 teaspoon of Benlate where powdery mildew is a problem on apples.
3	When three-fourths of the petals have fallen.	Same as No. 2 mix			See remarks for No. 2 mix.
4	7 to 10 days after No. 3 mix.	Same as No. 2 mix			See remarks for No. 2 mix.
5	Continue sprays at 7- to 10-day intervals until July 1.	Same as No. 2 mix			
6	Continue sprays at 10- to 14-day intervals until 2 weeks before harvest.	Same as No. 2 mix			

NOTES: Apply dormant sprays only when the temperature is above freezing and before buds show green tips.

Borers that attack apple and pear trees will be controlled by the spray schedule above if the trunk is thoroughly sprayed. If borers have attacked young, nonbearing trees, spray the trunks every 2 weeks during June and July with a multipurpose fruit spray.

For apple maggot control in the northern half of Illinois, continue to apply an insecticide or multipurpose fruit spray every 10 to 14 days through July and August.

Table 5. Spray Schedule for Grapes

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	New growth 2 to 4 inches long and again at 10 to 15 inches long.	Ferbam *plus* Sevin *or* Malathion, 25% WP	2 2 2	1½ 1 1	Primarily for black rot control; also for flea beetles.
2	Just before bloom	Same as No. 1 mix			If powdery mildew is a problem, add 1 teaspoon of benomyl (Benlate) per gallon to spray mix.
3	Just after bloom (when berries have set).	Captan *plus* Sevin (if needed)	1½ 2	1½ 1	Add Sevin if insects are a problem.
4	3 weeks after the last spray.	Captan	1½	1½	Primarily for black rot control.

NOTES: Grapes should be severely pruned and retied annually. Clean cultivation helps control flea beetles, cutworms, and disease-causing organisms. Select only strong, healthy canes of the previous year's growth to produce the following season's crop. After the fruiting canes have been selected, remove excess growth, dried berries, and leaves. Destroy (burn) all prunings.

The most important problem is black rot, which appears on the leaves as small, reddish-brown to tan-brown spots with dark margins. "Bird's-eye" tan spots on the fruit rapidly enlarge. Berries quickly rot and turn into black, wrinkled mummies that drop early.

Table 6. Spray Schedule for Currants and Gooseberries

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
1	Dormant (before growth starts).	Plant spray oil	5 tbsp.	3 cups	For control of scale and aphid insects.
2	When leaf tips show green.	Malathion, 57% EC *plus* wettable sulfur *or* Benlate *or* Karathane (if needed)	2 tsp. 3 tbsp. ½ tbsp. 2 tsp.	7 tbsp. 2 cups ½ cup ½ cup	Add 2 tablespoons of sulfur, 1 teaspoon of Benlate, or 2 teaspoons of Karathane to each gallon of the mix if powdery mildew is a problem.
3	Full foliage.	Malathion, 57% EC	2 tsp.	7 tbsp.	Same as for No. 2 mix.
4	2 weeks after bloom.	Ferbam	2 tbsp.	1½ cups	Mostly for leaf spot and anthracnose control.

NOTE: Prune out and destroy severely infested or diseased plant parts.

Table 7. Spray Schedule for Blueberries

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	As buds break open and until three-fourths of blossoms have dropped.	Malathion, 25% WP *or* Sevin *plus* Ferbam *or* Benlate	2 2 2 ½	1 1½ 1½ ½	If pest problems appear, apply at 10-day to 2-week intervals.

NOTES: Pruning out old canes and cleaning out small, weak wood with hand shears will reduce insect, mite, and disease problems. All prunings should be removed and disposed of, preferably by burning.

Heavy nitrogen fertilization increases the chances for more severe disease problems.

Table 8. Spray Schedule for Peaches, Nectarines, Apricots, and Plums

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	Dormant; *before* buds swell, *not later.*	Captan, OR multipurpose fruit spray	1½	1½	This is the *only* spray that controls leaf curl and plum pockets.
2	When fruit buds show color (or turn pink).	Captan OR Benlate[a]	1½ ½	1½ ½	Do *not* use insecticides during bloom: pollinating insects will be killed.
3	During bloom.	Captan OR Benlate[a]	1½ ½	1½ ½	Very important for blossom blight control.
4	When husks begin to split and pull away from the base of the fruit.	Wettable sulfur *plus* Captan *plus* Diazinon OR multipurpose fruit spray *plus* sulfur	3 1½ 1	2 1½ ¾	Sulfur is needed for scab control on peaches and may be added to a multipurpose fruit spray.
5	7 to 10 days after No. 4 mix.	Same as No. 4 mix			
6	Continue sprays at 10- to 14-day intervals until 4 weeks before harvest.	Same as No. 4 mix			
7	10 to 14 days after No. 6 mix.	Malathion, 25% WP *plus* Captan	1½ 2	1 2	Within 1 week of harvest, spray Captan alone for brown rot.

[a] Benlate should be either alternated or combined with Captan in the spray schedule to prevent the occurrence of Benlate-tolerant strains of fungi. *Never* use Benlate alone in repeated spray applications.

NOTE: For special borer sprays for peaches, nectarines, cherries, plums, and apricots, spray or paint *only* the trunk and lower limbs with 3 tablespoons of Sevin per gallon of water about June 15, July 15, and August 15.

Table 9. Spray Schedule for Cherries

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	When husks begin to split and pull away from the base of the fruit.	Captan *plus* Malathion, 25% WP *or* Diazinon, OR multipurpose fruit spray	1½ 1½ 1	1 1 ¾	
2	7 to 10 days after No. 1 mix.	Same as No. 1 mix			
3	Just after fruit is harvested and again 2 to 3 weeks later.	Captan	2	1½	Important to control leaf spot and to keep leaves from dropping prematurely.

NOTE: For special borer sprays for cherries, see the schedule for peaches. Cyprex and Benlate give outstanding control of cherry leaf spot and, if available, are recommended as a replacement for Captan in the spray program above.

Table 10. Spray Schedule for Strawberries

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
			tbsp.	*cups*	
1	Early bloom.	Multipurpose fruit spray *plus* Captan *or* Benlate[a]	 1½ 1	 1½ ½	Apply at the appearance of the first blossoms.
2	Cover sprays (7 to 10 days after No. 1 mix; repeat every 7 to 10 days until harvest.	Multipurpose fruit spray *or* Captan *or* Benlate[a]	 1½ ½	 1½ ½	Apply Captan or Benlate *alone*[a] during bloom at weekly intervals; Benlate, if powdery mildew develops.
3	Postharvest sprays.	Multipurpose fruit spray			Apply 1 or more times after renovation to protect the new foliage for next year's crop.

[a] Benlate should be either alternated or combined with Captan in the spray schedule to prevent the occurrence of Benlate-tolerant strains of fungi.

NOTE: To reduce insect and disease problems of strawberries —

1. Renovate beds immediately after each harvest.
2. Use certified, virus-free plants for new plantings. Plan a good aphid control program during spring and summer to reduce the chance of contaminating your virus-free plantings. Malathion is good against aphids.
3. Practice crop rotation. Because of Verticillium wilt, avoid planting within 3 years of tomatoes, peppers, potatoes, eggplant, melons, or roses. Strawberry varieties most resistant to Verticillium wilt include Allstar, Catskill, Delite, Earliglow, Guardian, Redchief, Sunrise, Surecrop, Tennessee Beauty, Tribute, and Tristar.
4. Plant red-stele-resistant varieties; this is the *only* control for this disease. Planting in light, well-drained soil may provide a measure of relief. The following strawberry varieties are resistant to red stele root rot (the number in parentheses is the number of races of the fungus to which the variety is resistant): Allstar (2), Darrow (5), Delite (5), Earliglow (5), Guardian (5), Midway (2), Redchief (5), Sunrise (5), Surecrop (5), Tribute (2), and Tristar (2).
5. Avoid white grubs. Do not plant strawberries on sod land until it has been under cultivation for at least 2 years. If grub damage is present, apply diazinon as a postharvest treatment.
6. If slugs are a problem, apply metaldehyde bait according to label directions.

Table 11. Spray Schedule for Brambles (Blackberries and Raspberries)

Mix no.	Time to apply	Spray material	For 1 gal.	For 10 gal.	Remarks
1	Delayed dormant (before leaflets are ⅜-inch long).	Liquid lime-sulfur	1½ cups	1 gal.	For control of mites, scale insects, anthracnose, and spur blight.
2	Cover sprays (when new canes are 6 to 8 inches high, just before bloom, and immediately after bloom).	Sevin *or* Malathion, 25% WP *plus* Ferbam	2 tbsp. 2 tbsp. 2 tbsp.	1 cup 1 cup 1½ cups	For control of anthracnose, spur blight, cane blight, fruit rots, leaf spot, and insects.
3	Special sprays.	Malathion, 25% WP	2 tbsp.	1 cup	Apply as fruit begins to color to control picnic beetles.
		Ferbam	2½ tbsp.	1½ cups	Apply right after harvest to control anthracnose and spur blight.

NOTE: to reduce insect and disease problems of brambles —

1. Remove and dispose of insect-infested, diseased, and old fruiting canes immediately after harvest. Thin out all weak, short, spindly, and injured canes. Clean cultivation helps control fruit worms.
2. Remove all nearby wild brambles and neglected plantings.
3. Keep fruit plantings and surrounding areas free of weeds.
4. Use certified, virus-free plants when starting a new planting. Select adapted, disease-resistant varieties.
5. All plants infected with orange rust, crown gall, and viruses must be dug out and removed from the planting when first noticed.
6. See strawberries spray schedule for note on Verticillium wilt control.

Table 12. Effectiveness of Fungicides against Specific Diseases

	Benomyl (Benlate)	Captan	Ferbam	Wettable Sulfur
Apple				
Scab	+++	++	+	+
Cedar rusts	0	0	++	0
Powdery mildew	++	0	0	++
Sooty blotch	+++	++	+	+
Stone fruits				
Brown rot of peach, plum, cherry, apricots	+++	++	–	+
Peach scab	++	++	–	++
Strawberry				
Leaf spots and blights	+++	++	–	–
Grey mold on ripening fruit	+++	++	–	–
Grape				
Black rot	+	++	+++	0
Downy mildew	0	+++	+	0
Powdery mildew	+++	0	0	+++
Raspberry				
Fruit rot, anthracnose, spur blight, cane blight	+++	++	–	–

NOTE: +++ = very good, ++ = good, + = fair, 0 = not effective, and – = not labeled for this use.

HANDLE PESTICIDES CAREFULLY

All pesticides should be handled with care. The materials suggested in this circular are relatively low in toxicity, but careless use can cause illness.

- Read the label and follow all precautions and directions.
- Keep pesticides in their original containers and lock them away from children, pets, food, and feeds.
- Avoid getting spray materials and spray on the skin. If an accident happens, wash the area liberally with soap and water IMMEDIATELY.
- Mix sprays in a well-ventilated area to avoid breathing spray dust and fumes.
- Wear a cap, a long-sleeved shirt, and full-length pants when spraying to protect the skin from spray drift. Avoid breathing the dust or spray.
- Don't smoke or eat while spraying or handling spray chemicals.
- Don't spray from inside a fruit tree.
- Wash hands and face with soap and water when spraying is finished.
- Avoid spray drift on vegetables, small fruits, birdbaths, fishponds, and water supplies of animals.
- Bury surplus pesticides and dispose of containers in a manner that will prevent their reuse.

AVAILABLE PUBLICATIONS

Control of pests is dependent on a rapid and accurate diagnosis. A number of entomology Fact Sheets (NHE's) and Reports on Plant Diseases (RPD's) covering most fruit pests are available. Contact your county Extension office concerning the availability of these publications.

This circular was prepared by M. C. Shurtleff and S. M. Ries, Extension Specialists in Plant Pathology, Roscoe Randell, Extension Specialist in Entomology, and D. B. Meador, Extension Specialist in Horticulture.

Application Equipment and Calibration References

L. Bode and R. Wolf

SPRAYER CALIBRATION GUIDELINES

Variables Affecting Application Rate

Three variables affect the amount of spray mixture applied per acre: (1) the nozzle flow rate; (2) the ground speed of the sprayer; and (3) the effective sprayed width per nozzle.

The gallons of spray applied per acre can be determined from the three variables in the following equation:

$$GPA = \frac{GPM \times 5940}{MPH \times W}$$

When:

GPA = spray applied, in gallons per acre.

GPM = output per nozzle, in gallons per minute.

MPH = ground speed, in miles per hour.

W = effective sprayed width per nozzle, in inches.
For broadcast spraying, W = the nozzle spacing.
For band spraying, W = the band width.
For row crop applications, such as spraying from drop pipes or directed spraying, $W = \frac{\text{row spacing (or band width)}}{\text{number of nozzles per row (or band)}}$.

5940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre.

Selecting the Proper Nozzle Tip

The proper size nozzle can be selected by determining the required flow rate from each nozzle at a selected application rate (GPA), ground speed (MPH), and

EQUIPMENT

effective sprayed width in inches (W) per nozzle. The required flow rate per nozzle can be determined from one of the following equations:

$$GPM = \frac{GPA \times MPH \times W}{5940}$$

or

$$OPM = \frac{GPA \times MPH \times W}{46.4}$$

When:

OPM = output per nozzle, in ounces per minute

Select a nozzle that will give the required flow rate when the nozzle is operated within the recommended pressure range. The tables on the following pages list the flow rates from commonly used nozzles that are available from several manufacturers.

Calibrating the Sprayer

Install the selected nozzle tips in the sprayer. Determine the required flow rate for each nozzle in ounces per minute (OPM) from the following equation:

$$OPM = GPM \times 128$$
(1 gallon = 128 ounces)

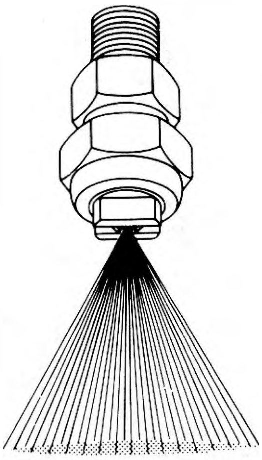
Collect the output from a nozzle using a container marked in ounces. Adjust the pressure until the required OPM is collected. Check the nozzle flow rate frequently. Adjust the pressure to compensate for small changes in nozzle output resulting from nozzle wear. Replace the nozzle tips and recalibrate when the output has changed 10 percent or more from that of a new nozzle, or when the pattern has become uneven.

Types of spray nozzles are shown on the next two pages.

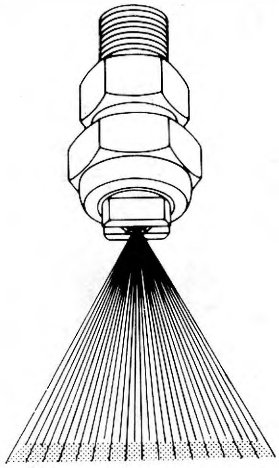
NOZZLE NOMENCLATURE

There are many types of nozzles available, each providing different flow rates, spray angles, and droplet sizes and patterns. The tip number is often used to indicate some of these spray characteristics. Other indications for spray characteristics are identified with letters representing different operating conditions. The following table is presented to help classify various nozzles and their spray characteristics.

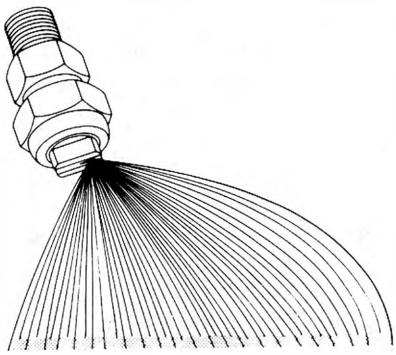
TYPES OF SPRAY NOZZLES



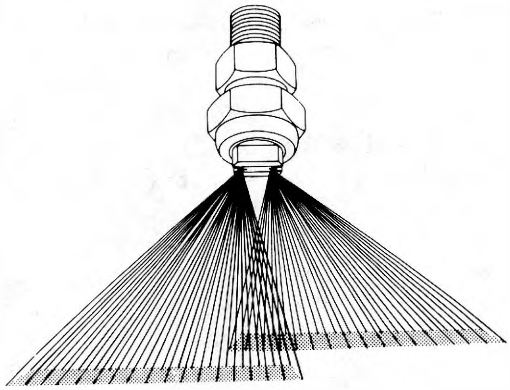
Flat Fan



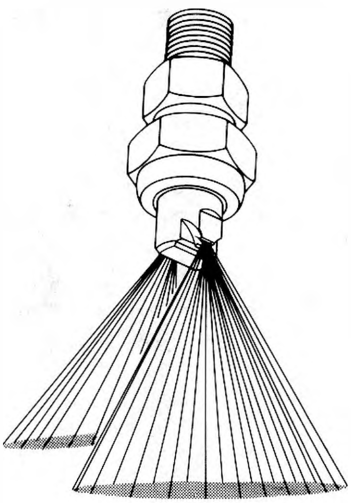
Even Fan



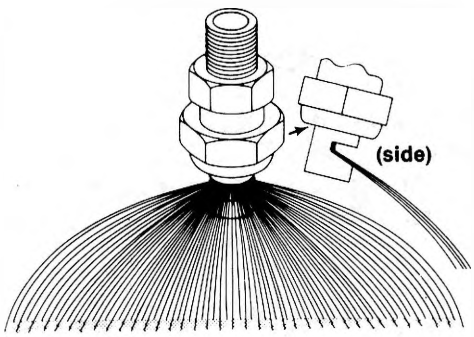
Off Center Fan



Twin Orifice (Off – Center)

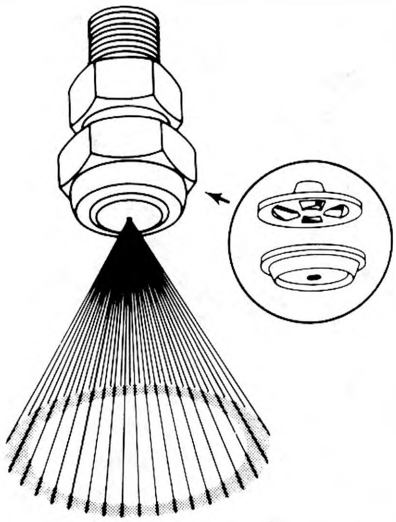


Twin Orifice (Flat Fan)

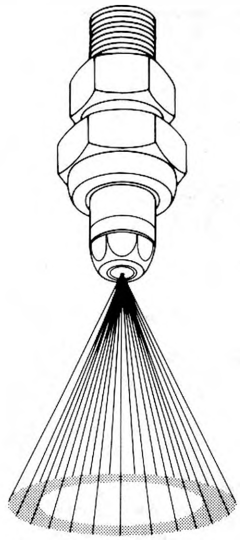


Flooding (front)

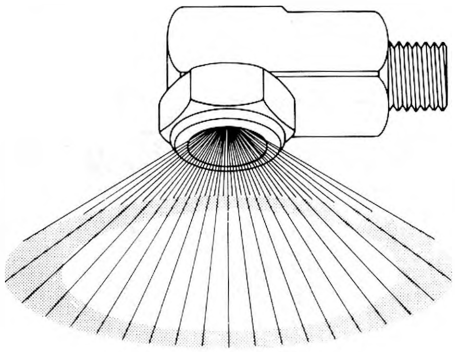
TYPES OF SPRAY NOZZLES



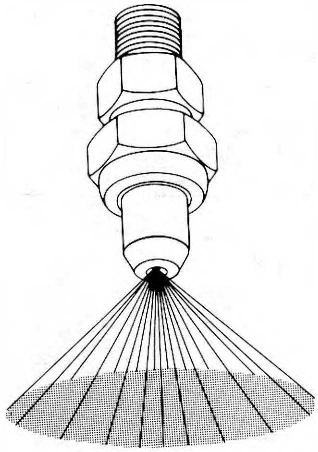
Hollow Cone (Disc – Core)



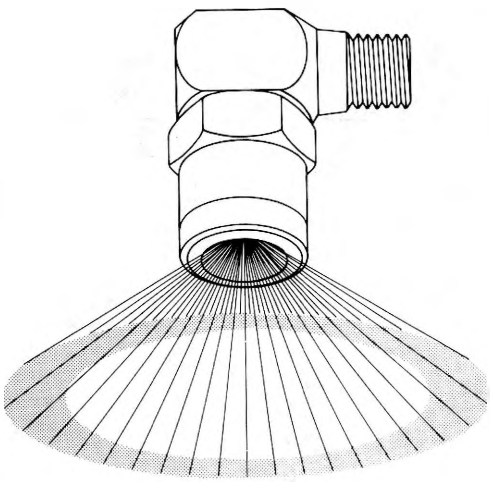
Hollow Cone (1 piece)



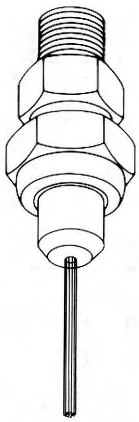
Swirl Chamber



Wide Angle Full Cone



RA – Raindrop



Straight Stream

Nozzle type	Nozzle Nomenclature: Delavan	Spraying systems	Lurmark	Chem Farm
flat fan (regular, extended range)	LF, LFR, R	XR	F	
even fan	LE	E	E	
low pressure flat fan		LP		
twin orifice and twin orifice even	2LF	TJ, TJE		
off center	LX	OC	OC	
flooding	D or F	TK or K	AN	
whirlchamber, Raindrop, wide angle-full cone	WRW, RA	FL, B, W	HW	MC
hollow-cone	HB, HC	TX	HAF	
hollow-cone (disc and core type)	DC	D	DC	
flooding, Raindrop, and whirlchamber (high capacity)	F, 3/4 WRW	K, QCK	AN	

FLAT-FAN NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity: gal/min (GPM)	oz/min (OPM)
Spraying Systems 800067	15	.04	5.1
Delavan LF.67	20	.05	6.4
	30	.06	7.7
(100 mesh)	40	.067	8.6
	50	.07	9.0
Spraying Systems XR8001	15	.06	7.7
	20	.07	9.0
Lurmark 01-F80	30	.09	11.5
Hardi 2080-10	40	.10	12.8
(100 mesh)	50	.11	14.1
Spraying Systems XR80015	15	.09	11.5
Delavan 80-1.5 (80-1.5R)	20	.11	14.1
Lurmark 015-F80	30	.13	16.6
Hardi 2080-12	40	.15	19.2
(100 mesh)	50	.17	21.8
Spraying Systems XR8002	15	.12	15.4
Delavan 80-2 (80-2R)	20	.14	17.9
Lurmark 02-F80	30	.17	21.8
Hardi 2080-14	40	.20	25.6
(50 mesh)	50	.23	29.4

FLAT-FAN NOZZLES *(continued)*

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems XR8003	15	.18	23.0
Delavan 80-3 (80-3R)	20	.21	26.9
Lurmark 03-F80	30	.26	33.3
Hardi 2080-16	40	.30	38.4
(50 mesh)	50	.34	43.5
Spraying Systems XR8004	15	.24	30.7
Delavan 80-4 (80-4R)	20	.28	35.8
Lurmark 04-F80	30	.35	44.8
Hardi 2080-20	40	.40	51.2
(50 mesh)	50	.45	57.6
Spraying Systems XR8005	15	.31	39.7
Delavan 80-5 (80-5R)	20	.35	44.8
Lurmark 05-F80	30	.43	55.0
	40	.50	64.0
(50 mesh)	50	.56	71.7
Spraying Systems XR8006	15	.37	47.4
Delavan 80-6 (80-6R)	20	.42	53.7
Lurmark 06-F80	30	.52	66.6
Hardi 2080-24	40	.60	76.8
(50 mesh)	50	.67	85.8
Spraying Systems XR8008	15	.49	62.7
Delavan 80-8 (80-8R)	20	.57	73.0
Lurmark 08-F80	30	.69	88.3
Hardi 2080-30	40	.80	102.0
(50 mesh)	50	.89	114.0
Spraying Systems XR8010	15	.61	78.1
Delavan 80-10	20	.71	90.9
Lurmark 10-F80	30	.87	111.4
Hardi 2080-36	40	1.00	128.0
	50	1.12	143.4
Spraying Systems XR8015	15	.92	117.8
Delavan 80-15	20	1.06	136.0
Lurmark 15-F80	30	1.30	166.0
	40	1.50	192.0
	50	1.68	215.0
Spraying Systems XR8020	15	1.20	153.6
Delavan 80-20	20	1.41	180.0
Lurmark 20-F80	30	1.73	221.0
Hardi 2080-50	40	2.00	256.0
	50	2.23	285.4

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

EVEN FAN NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan 80-1E Spraying Systems 8001E Lurmark E9501 (100 mesh)	20 25 30 40	.07 .08 .09 .10	9.0 10.2 11.5 12.8
Delavan 80-1.5E Spraying Systems 80015E Lurmark E95015 (100 mesh)	20 25 30 40	.11 .12 .13 .15	14.1 15.4 16.6 19.2
Delavan 80-2E Spraying Systems 8002E Lurmark E9502 (50 mesh)	20 25 30 40	.14 .16 .17 .20	17.9 20.5 21.8 25.6
Delavan 80-3E Spraying Systems 8003E Lurmark E9503 Hardi 4598-10 (50 mesh)	20 25 30 40	.21 .24 .26 .30	26.9 30.7 33.3 38.4
Delavan 80-4E Spraying Systems 8004E Lurmark E9504 Hardi 4598-12 (50 mesh)	20 25 30 40	.28 .32 .35 .40	35.8 41.0 44.8 51.2
Delavan 80-5E Spraying Systems 8005E Lurmark E9505 Hardi 4598-14 (50 mesh)	20 25 30 40	.35 .40 .43 .50	44.8 51.2 55.0 64.0
Delavan 80-6E Spraying Systems 8006E Lurmark E9506 Hardi 4598-16 (50 mesh)	20 25 30 40	.42 .47 .52 .60	53.7 60.2 66.6 76.8
Delavan 80-8E Spraying Systems 8008E Lurmark E9508 Hardi 4598-18 (50 mesh)	20 25 30 40	.57 .63 .69 .80	73.0 80.6 88.3 102.0
Delavan 80-10E Spraying Systems 8010E Lurmark E9510	20 25 30 40	.71 .79 .87 1.00	91.0 101.0 111.0 128.0
Delavan 80-15E Spraying Systems 8015E Lurmark E9515 Hardi 4598-20	20 25 30 40	1.06 1.19 1.30 1.50	136.0 152.0 166.0 192.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

LOW PRESSURE FLAT-FAN NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems 8001LP (100 mesh)	15	.10	12.8
	20	.12	15.4
	30	.14	17.9
	40	.16	20.5
Spraying Systems 80015LP (50 mesh)	15	.15	19.2
	20	.17	21.8
	30	.21	26.9
	40	.24	30.7
Spraying Systems 8002LP (50 mesh)	15	.20	25.6
	20	.23	29.4
	30	.28	35.8
	40	.33	42.2
Spraying Systems 8003LP (50 mesh)	15	.30	38.4
	20	.35	44.8
	30	.42	53.7
	40	.49	62.7
Spraying Systems 8004LP (50 mesh)	15	.40	51.2
	20	.46	58.9
	30	.57	73.0
	40	.65	83.2
Spraying Systems 8005LP (50 mesh)	15	.50	64.0
	20	.58	74.2
	30	.71	91.0
	40	.82	105.0
Spraying Systems 8006LP	15	.60	76.8
	20	.69	88.3
	30	.85	109.0
	40	.98	125.0
Spraying Systems 8008LP	15	.80	102.0
	20	.92	115.0
	30	1.11	41.0
	40	1.30	166.0
Spraying Systems 8010LP	15	1.00	128.0
	20	1.20	154.0
	30	1.40	179.0
	40	1.60	205.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

TWIN ORIFICE FAN NOZZLES AND TWIN ORIFICE EVEN NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems 15001	20	.07	9.0
	30	.09	11.5
	40	.10	12.8
(200 mesh)	50	.11	14.1
	60	.12	15.4
Spraying Systems 150015	20	.11	14.1
Delavan 2LF 1.5	30	.13	16.6
	40	.15	19.2
(100 mesh)	50	.17	21.8
	60	.18	23.0
Spraying Systems 15002	20	.14	17.9
Delavan 2LF-2	30	.17	21.8
Spraying Systems TJ60-8002	40	.20	25.6
and TJ60-8002E	50	.22	28.2
(100 mesh)	60	.25	32.0
Spraying Systems 15003	20	.21	26.9
Delavan 2LF-3	30	.26	33.3
Spraying Systems TJ60-8003	40	.30	38.4
and TJ60-8003E	50	.34	43.5
(100 mesh)	60	.37	47.4
Spraying Systems 15004	20	.28	35.8
Delavan 2LF-4	30	.35	44.8
Spraying Systems TJ60-8004	40	.40	51.2
and TJ60-8004E	50	.45	57.6
(50 mesh)	60	.49	62.7
Spraying Systems 15005	20	.35	44.8
Delavan 2LF-5	30	.43	55.0
	40	.50	64.0
(50 mesh)	50	.56	71.7
	60	.61	78.1
Spraying Systems 15006	20	.42	53.7
Delavan 2LF-6	30	.52	66.6
Spraying Systems TJ60-8006	40	.60	76.8
and TJ60-8006E	50	.67	85.8
(50 mesh)	60	.74	94.7
Spraying Systems 15008	20	.57	73.0
Delavan 2LF-8	30	.69	88.3
Spraying Systems TJ60-8008	40	.80	102.0
	50	.89	114.0
(50 mesh)	60	.98	125.0
Spraying Systems 15009	20	.64	81.9
Delavan 2LF-9	30	.78	99.8
	40	.90	115.0
(50 mesh)	50	1.00	128.0
	60	1.10	141.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

OFF-CENTER FAN NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	oz/min (OPM)
Delavan LX-2 Spraying Systems OC-02 Lurmark OC2 (50 mesh)	20	.14	17.9
	30	.17	21.8
	40	.20	25.6
	60	.24	30.7
Delavan LX-3 Spraying Systems OC-03 Lurmark OC3 Hardi G150 (50 mesh)	20	.21	26.9
	30	.26	33.3
	40	.30	38.4
	60	.37	47.4
Delavan LX-4 Spraying Systems OC-04 Lurmark OC4 Hardi G200 (50 mesh)	20	.28	35.8
	30	.35	44.8
	40	.40	51.2
	60	.49	62.7
Delavan LX-6 Spraying Systems OC-06 Lurmark OC6 (50 mesh)	20	.42	53.8
	30	.52	66.6
	40	.60	76.8
	60	.73	93.4
Delavan LX-8 Spraying Systems OC-08 Lurmark OC8 Hardi G250 (50 mesh)	20	.57	73.0
	30	.69	88.3
	40	.80	102.4
	60	.98	125.4
Delavan LX-12 Spraying Systems OC-12 Lurmark OC12	20	.85	108.8
	30	1.00	128.0
	40	1.20	153.6
	60	1.50	192.0
Delavan LX-16 Spraying Systems OC-16 Lurmark OC16	20	1.11	40.8
	30	1.41	79.2
	40	1.60	204.8
	60	2.00	256.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

FLOODING NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	oz/min (OPM)
Spraying Systems TK-.5	10	.05	6.4
Lurmark AN0.5	20	.07	9.0
	30	.08	10.2
(100 mesh)	40	.10	12.8
Delavan D.75 (F.75)	10	.075	9.6
Spraying Systems TK-.75	20	.11	14.1
Lurmark AN0.75	30	.13	16.7
(100 mesh)	40	.15	19.2
Delavan D1 (F1)	10	.10	12.8
Spraying Systems TK-1	20	.14	17.9
Lurmark AN1	30	.17	21.8
(100 mesh)	40	.20	25.6
Delavan D1.5 (F1.5)	10	.15	19.2
Spraying Systems TK-1.5	20	.21	26.9
Lurmark AN1.5	30	.26	33.3
(50 mesh)	40	.30	38.4
Delavan D2 (F2)	10	.20	25.6
Spraying Systems TK-2	20	.28	35.8
Lurmark AN2	30	.35	44.8
(50 mesh)	40	.40	51.2
Delavan D2.5 (F2.5)	10	.25	32.0
Spraying Systems TK-2.5	20	.35	44.8
Lurmark AN2.5	30	.43	55.0
(50 mesh)	40	.50	64.0
Delavan D3 (F3)	10	.30	38.4
Spraying Systems TK-3	20	.42	53.8
Lurmark AN3	30	.52	66.6
(50 mesh)	40	.60	76.8
Delavan D4 (F4)	10	.40	51.2
Spraying Systems TK-4	20	.57	73.0
Lurmark AN4	30	.69	88.3
	40	.80	102.4
Delavan D5 (F5)	10	.50	64.0
Spraying Systems TK-5	20	.71	90.9
Lurmark AN5	30	.87	111.4
	40	1.00	128.0

FLOODING NOZZLES, *continued*

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan D6	10	.60	76.8
	20	.85	108.8
	30	1.0	128.0
	40	1.2	153.6
Delavan D7.5 (F7.5) Spraying Systems TK-7.5 Lurmark AN7.5	10	.75	96.0
	20	1.11	142.1
	30	1.31	167.7
	40	1.5	192.0
Delavan D10 (F10) Spraying Systems TK-10 Lurmark AN10	10	1.0	128.0
	20	1.4	179.2
	30	1.7	217.6
	40	2.0	256.0
Delavan D15 (F15) Spraying Systems TK-15	10	1.5	192.0
	20	2.1	268.8
	30	2.6	332.8
	40	3.0	384.0
Delavan D20 (F20) Spraying Systems TK-20 Lurmark AN20	10	2.0	256.0
	20	2.8	358.4
	30	3.5	448.0
	40	4.0	512.0
Spraying Systems TK-30 Delavan (F30)	10	3.0	384.0
	20	4.2	537.6
	30	5.2	565.6
	40	6.0	768.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

WHIRLCHAMBER, RAINDROP, AND WIDE ANGLE FULL CONE NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan 1/4WRW2	10	.10	12.8
Delavan RA-2	20	.14	17.9
Lurmark HW2	30	.17	21.8
	40	.20	25.6
(50 mesh)	50	.22	28.2
	60	.24	30.7
Chem Farm MC1.25	10	.13	16.6
	20	.18	23.0
	30	.22	28.2
	40	.25	32.0
	50	.28	35.8
	60	.31	39.7
Delavan 1/4WRW4	10	.20	25.6
Delavan RA-4	20	.28	35.8
Lurmark HW4	30	.35	44.8
	40	.40	51.2
(50 mesh)	50	.45	57.6
	60	.49	62.7
Delavan 1/4WRW5	10	.25	32.0
Delavan RA-5	20	.35	44.8
Spraying Systems FL-5	30	.43	55.0
Chem Farm MC2.5	40	.50	64.0
(50 mesh)	50	.56	71.7
	60	.61	78.1
Delavan 1/4WRW6	10	.30	38.4
Delavan RA-6	20	.42	53.8
Lurmark HW6	30	.52	66.6
	40	.60	76.8
(50 mesh)	50	.67	85.8
	60	.73	93.4
Delavan RA8	10	.40	51.2
Spraying Systems FL-8	20	.57	73.0
	30	.70	89.6
	40	.80	102.4
	50	.90	115.2
	60	.99	126.7
Delavan 1/4WRW10	10	.50	64.0
Spraying Systems 1/4B-SS5-5W	20	.71	90.8
Delavan RA-10	30	.87	111.4
Spraying Systems FL-10	40	1.00	128.0
Lurmark HW10	50	1.10	140.8
	60	1.20	153.6

WHIRLCHAMBER, RAINDROP, AND WIDE ANGLE FULL CONE NOZZLES, *continued*

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan 1/4WRW15 Delavan RA-15 Spraying Systems FL-15 Lurmark HW15	10	.75	96.0
	20	1.10	140.8
	30	1.30	166.4
	40	1.50	192.0
	50	1.70	217.6
	60	1.80	230.4
Delavan 1/4WRW20 Spraying Systems 1/4B-SS10-10W Lurmark HW20	10	1.00	128.0
	20	1.40	179.2
	30	1.70	217.6
	40	2.00	256.0
	50	2.20	281.6
	60	2.40	307.2

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

HOLLOW-CONE NOZZLES

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan HB-1 (HC-1) Spraying Systems TX1 Lurmark HAF0180 (100 mesh)	30	.0145	1.8
	40	.0167	2.1
	60	.0200	2.6
	75	.0233	3.0
	90	.0250	3.2
Delavan HB-2 (HC-2) Spraying Systems TX2 Lurmark HAF0280 (100 mesh)	30	.0283	3.6
	40	.0333	4.3
	60	.0400	5.1
	75	.0450	5.8
	90	.0500	6.4
Delavan HB-3 (HC-3) Spraying Systems TX3 Lurmark HAF0380 (100 mesh)	30	.0433	5.5
	40	.0500	6.4
	60	.0617	7.9
	75	.0683	8.7
	90	.0750	9.6
Delavan HB-4 (HC-4) Spraying Systems TX4 Lurmark HAF0480 (50 mesh)	30	.0583	7.5
	40	.0667	8.5
	60	.0817	10.5
	75	.0917	11.7
	90	.1000	12.8
Delavan HB-6 (HC-6) Spraying Systems TX6 Lurmark HAF0680 (50 mesh)	30	.0867	11.1
	40	.1000	12.8
	60	.1217	15.6
	75	.1367	17.5
	90	.1500	19.2
Delavan HB-8 (HC-8) Spraying Systems TX8 Lurmark HAF0880 (50 mesh)	30	.1150	14.7
	40	.1333	17.1
	60	.1633	20.9
	75	.1833	23.5
	90	.2000	25.6
Delavan HB-10 (HC-10) Spraying Systems TX10 Lurmark HAF1080 (50 mesh)	30	.1450	18.6
	40	.1667	21.3
	60	.2033	26.0
	75	.2283	29.2
	90	.2500	32.0
Delavan HB-12 (HC-12) Spraying Systems TX12 Lurmark HAF1280 (50 mesh)	30	.1733	22.2
	40	.2000	25.6
	60	.2450	31.4
	75	.2733	35.0
	90	.3000	38.4

HOLLOW-CONE NOZZLES, *continued*

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan HB-18 (HC-18)	30	.2600	33.3
Spraying Systems TX18	40	.3000	38.4
Lurmark HAF1880	60	.3667	46.9
(50 mesh)	75	.4100	52.5
	90	.4500	57.6
Delavan HB-26 (HC-26)	30	.3750	48.0
Spraying Systems TX26	40	.4333	55.5
Lurmark HAF2680	60	.5300	67.8
(50 mesh)	75	.5933	75.9
	90	.6500	83.2

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

HOLLOW-CONE NOZZLES (DISC AND CORE TYPE)

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan DC2-13 Spraying Systems D2-13 Lurmark 2-13 Hardi 1553-10 Blue Swirl (50 mesh)	40 60 80 100 150	.08 .10 .11 .12 .14	10.2 12.8 14.1 15.4 17.9
Delavan DC2-23 Spraying Systems D2-23 Lurmark 2-23 (50 mesh)	40 60 80 100 150	.10 .13 .14 .16 .19	12.8 16.6 17.9 20.5 24.3
Delavan DC3-23 Spraying Systems D3-23 Lurmark 3-23 (25 mesh)	40 60 80 100 150	.12 .14 .16 .18 .21	15.4 17.9 20.5 23.0 26.9
Delavan DC2-25 Spraying Systems D2-25 Lurmark 2-25 Hardi 1553-10 Black Swirl (25 mesh)	40 60 80 100 150	.16 .19 .22 .25 .29	20.5 24.3 28.2 32.0 37.1
Delavan DC3-25 Spraying Systems D3-25 Lurmark 3-25 Hardi 1553-22 Blue Swirl (25 mesh)	40 60 80 100 150	.19 .23 .26 .29 .35	24.3 29.4 33.3 37.1 44.8
Delavan DC3-45 Spraying Systems D3-45 Lurmark Hardi 1553-30 Blue Swirl (25 mesh)	40 60 80 100 150	.23 .28 .33 .36 .44	29.4 35.8 42.2 46.1 56.3
Delavan DC4-25 Spraying Systems D4-25 Lurmark 4-25 Hardi 1553-40 Blue Swirl (25 mesh)	40 60 80 100 150	.29 .35 .40 .45 .54	37.1 44.8 51.2 57.6 69.1
Delavan DC5-25 Spraying Systems D5-25 Lurmark 5-25 Hardi 1553-16 Gray Swirl (25 mesh)	40 60 80 100 150	.35 .42 .48 .54 .65	44.8 53.8 61.4 69.1 83.2
Delavan DC4-45 Spraying System D4-45 Lurmark 4-45 Hardi 1553-18 Gray Swirl (25 mesh)	40 60 80 100 150	.36 .43 .50 .56 .68	46.1 55.0 64.0 71.7 89.0

HOLLOW-CONE NOZZLES (DISC AND CORE TYPE), *continued*

Manufacturer tip no.*, (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan DC5-45 Spraying System D5-45 Lurmark 5-45 Hardi 1553-20 Gray Swirl (25 mesh)	40	.45	57.6
	60	.55	70.4
	80	.64	81.9
	100	.71	90.9
	150	.86	110.1
Delavan DC7-25 Spraying System D7-25 Lurmark 7-25 Hardi 1553-24 Gray Swirl (16 mesh)	40	.52	66.6
	60	.63	80.6
	80	.73	93.4
	100	.81	103.7
	150	.98	125.4
Delavan DC6-45 Spraying System D6-45 Lurmark 6-45 Hardi 1553-22 Black Swirl (16 mesh)	40	.58	74.24
	60	.72	92.2
	80	.83	106.2
	100	.93	119.0
	150	1.15	147.2
Delavan DC7-45 Spraying System D7-45 Lurmark 7-45 Hardi 1553-24 Black Swirl (16 mesh)	40	.68	87.0
	60	.84	107.5
	80	.97	124.2
	100	1.11	142.1
	150	1.35	172.8
Delavan DC8-45 Lurmark 8-45 Hardi 1553-30 Black Swirl (16 mesh)	40	.84	107.5
	60	1.04	133.1
	80	1.21	154.9
	100	1.35	172.8
	150	1.68	215.0
Delavan DC12-25 Spraying System D12-25 Lurmark 12-25 (16 mesh)	40	.93	119.0
	60	1.15	147.2
	80	1.32	169.0
	100	1.47	188.2
	150	1.81	231.7
Delavan DC12-45 Spraying Systems D12-45 Lurmark 12-45 (16 mesh)	40	1.36	174.1
	60	1.68	215.0
	80	1.95	249.6
	100	2.20	281.6
	150	2.69	344.3
Delavan DC8-46 Spraying Systems D8-46 (16 mesh)	40	1.84	235.5
	60	2.25	288.0
	80	2.62	335.4
	100	2.93	375.0
	150	3.60	460.8
Delavan DC10-46 Spraying System D10-46 (16 mesh)	40	2.48	317.4
	60	3.05	390.4
	80	3.53	451.8
	100	3.96	506.9
	150	4.83	618.2

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

FLOODING, RAINDROP, AND WHIRLCHAMBER NOZZLES (HIGH-CAPACITY)

Manufacturer tip no.* (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)
Delavan F20 Spraying Systems 1/8K-20 Delavan RA-40 Spraying Systems QCK-SS20 Delavan 3/4 WRW40 Lurmark AN20	10 20 30 40 50	2.0 2.8 3.5 4.0 4.5
Delavan F30 Spraying Systems 3/8K-30 Delavan RA-60 Spraying Systems QCK-SS30 Delavan 3/4 WRW60 Lurmark AN30	10 20 30 40 50	3.0 4.2 5.2 6.0 6.7
Delavan F40 Spraying Systems 3/8K-40 Delavan RA-80 Spraying Systems QCK-SS40 Delavan 3/4 WRW80 Lurmark AN40	10 20 30 40 50	4.0 5.7 6.9 8.0 9.0
Delavan F50 Spraying Systems 1/2K-50 Delavan RA-100 Spraying Systems QCK-SS60 Delavan 3/4 WRW100 Lurmark AN50	10 20 30 40 50	5.0 7.1 8.7 10.0 10.5
Delavan F60 Spraying Systems 1/2K-60 Delavan RA-120 Spraying Systems QCK-SS60 Delavan 3/4 WRW120 Lurmark AN60	10 20 30 40 50	6.0 8.5 10.4 12.0 13.4
Delavan F80 Spraying Systems 1/2K-80 Spraying Systems QCK-SS80 Delavan RA-160 Delavan 3/4 WRW160 Lurmark AN80	10 20 30 40 50	8.0 11.3 13.9 16.0 17.9
Delavan F100 Spraying Systems 3/4K-100 Delavan RA200 Spraying Systems QCK-SS100 Delavan 3/4 WRW200 Lurmark AN100	10 20 30 40 50	10.0 14.1 17.3 20.0 22.3

FLOODING, RAINDROP, AND WHIRLCHAMBER NOZZLES (HIGH-CAPACITY), *continued*

Manufacturer tip no.* (Nozzle screen size)	Liquid pressure (psi)	Capacity gal/min (GPM)
Delavan F120 Spraying Systems 3/4K-20 Delavan RA-240 Spraying Systems QCK-SS120 Delavan 3/4 WRW240 Lurmark AN120	10 20 30 40 50	12.0 17.0 20.8 24.0 26.8
Delavan F150 Delavan RA-300 Spraying Systems QCK-SS150	10 20 30 40 50	15.0 21.2 26.0 30.0 33.5
Delevan F180 Spraying Systems QCK-SS180	10 20 30 40	18.0 25.5 31.2 36.0
Delavan F210 Spraying Systems 3/4K-210 Spraying Systems QCK-SS210 Lurmark AN210	10 20 30 40	21.0 29.7 36.4 42.0
Spraying Systems 1K-300	10 20 30 40	30.0 42.4 52.0 60.0
Spraying Systems 1K-450	10 20 30 40	45.0 63.6 77.9 90.0

*Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

FLOW RATE

Nozzle flow rate varies with spraying pressure. The relationship between GPM and pressure is as follows:

$$\frac{GPM_1}{GPM_2} = \frac{\sqrt{PSI_1}}{\sqrt{PSI_2}}$$

With the above relationship, doubling the flow through the nozzle requires increasing the pressure four times. The above equation can be used to determine nozzle flow rates achieved at various pressures.

EXAMPLE:

If a certain nozzle achieved a flow rate of .10 GPM at a pressure of 40 PSI, what would that same nozzle flow rate be at 15 PSI?

SOLUTION

Rearrange the above formula to achieve GPM_2.

$$GPM_2 = \frac{\sqrt{PSI_2} \text{ X } GPM_1}{\sqrt{PSI_1}}$$

Solve for the new pressure.

$$GPM_2 = \frac{\sqrt{15 \text{ PSI}} \text{ x } .10 \text{ GPM}}{\sqrt{40 \text{ PSI}}}$$

$$GPM_2 = \frac{3.873 \text{ x } .10}{6.325}$$

$$GPM_2 = .06$$

MEASURING GROUND SPEED

To measure ground speed, mark off a distance in the field to be sprayed or in a field with similar surface conditions. Suggested distances are 100 feet for speeds up to 5 miles per hour, 200 feet for speeds from 5 to 10 miles per hour, and at least 300 feet for speeds above 10 miles per hour. At the engine throttle setting and gear used for actual spraying, determine the travel time between the measured stakes. Calculate ground speed using the following formula or look up the speed in the table below:

$$\text{Travel speed (MPH)} = \frac{\text{distance (feet)} \times 60}{\text{time (seconds)} \times 88}$$

Travel Speeds

Speed (miles per hour)	Time required to travel a distance in seconds		
	100 feet	200 feet	300 feet
3.0	23	45	68
3.5	20	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41
6.0		23	34
7.0		19	29
7.5		18	27
8.0		17	26
9.0		15	23
10.0		14	20
12.0			17
15.0			14

EFFECT OF SOLUTION DENSITY ON NOZZLE FLOW RATE

Density is the weight of a solution per unit volume (lb/gal). Specific gravity (SG) is the weight of a solution relative to water, which weighs 8.34 lb/gal. Nozzle flow rate varies inversely with the square root of specific gravity. Conversion factors to compare flow rates of solutions of any known density can be calculated by:

$$\text{Conversion Factor} = \sqrt{SG}$$

The following table can be used to predict the flow rate from various solutions and to select the proper nozzle size from a nozzle catalog table. Because nozzle tables are based on spraying water, the conversion factors from the table can be multiplied by the desired GPM or GPA to determine the water flow rate for the solution being sprayed. Use the converted GPM or GPA to select the proper nozzle size from the catalog.

Specific Gravity and Conversion Factor for Selected Solution Weights

Weight of solution (lb/gal)	Specific gravity	Conversion factor
7.0	.84	.92
8.0	.96	.98
8.34*	1.00	1.00
9.0	1.08	1.04
10.0	1.20	1.10
10.65**	1.28	1.13
11.0	1.32	1.15
12.0	1.44	1.20
14.0	1.68	1.30

*Water
**28% Nitrogen
NOTE: This table is based on theoretical solution densities only and may vary in actual practice because of differing solution characteristics. Applies to flood nozzles but not Raindrop nozzles.

Example: 3 GPM (28% N) x 1.13 = 3.39 GPM (water)

If the flow rate (GPM) or application rate (GPA) of water is known, the GPM or GPA of a solution can be predicted by dividing the flow or application rate by the conversion factor.

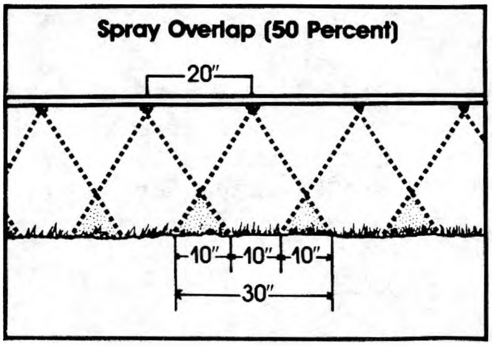
Example: 20 GPA (water) ÷ 1.13 = 17.7 GPA (28% N)

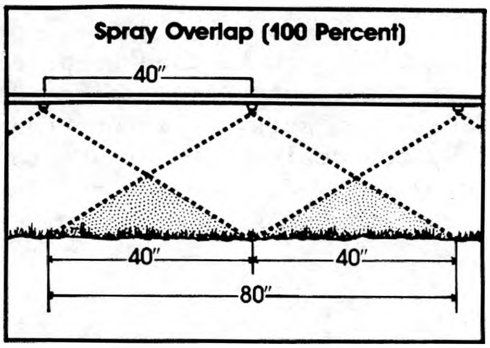
SPRAY OVERLAP

For uniform application each nozzle type must be operated at a spacing and height that provides a specific spray overlap. The overlap may vary from 30 percent to over 100 percent. The percent overlap or spray coverage can be calculated from the following formulas:

$$\text{Percent overlap} = \frac{\text{Spray Coverage - Nozzle Spacing}}{\text{Nozzle Spacing}}$$

Spray Coverage = (Nozzle Spacing x percent overlap) + Nozzle Spacing

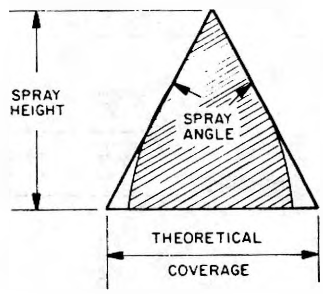




Spray Coverage Required to Obtain Proper Overlap

Overlap (%)	Spray Coverage at Various Nozzle Spacings 20"	25"	30"	35"	40"	50"	60"
20	24	30	36	42	48	60	72
30	26	33	39	46	52	65	78
40	28	35	42	49	56	70	84
50	30	38	45	53	60	75	90
60	32	40	48	56	64	80	96
70	34	43	51	60	68	85	102
80	36	45	54	63	72	90	108
90	38	48	57	67	76	95	114
100	40	50	60	70	80	100	120
110	42	53	63	74	84	105	126
150	50	63	75	88	100	125	150

SPRAY ANGLE COVERAGE AT VARIOUS HEIGHTS



The following table lists the theoretical coverage of spray patterns as calculated from the included spray angle of the spray and the distance from the nozzle orifice. These values are based on the assumption that the spray angle remains the same throughout entire spray distance. In actual practice, the tabulated spray angle does not hold for long spray distances.

Computed Spray Coverage

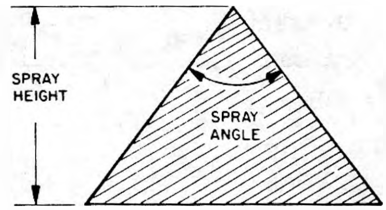
Spray angle (degrees)	Width of spray pattern at various distances from nozzle orifice 2"	4"	6"	8"	10"	12"	15"	18"	24"	30"	36"	42"	48"	60"
15	.5	1.1	1.6	2.1	2.6	3.2	3.9	4.7	6.3	7.9	9.5	11.1	12.6	15.8
25	.9	1.7	2.7	3.5	4.4	5.3	6.6	8.0	10.6	13.3	15.9	18.6	21.2	26.6
30	1.1	2.1	3.2	4.3	5.4	6.4	8.0	9.7	12.8	16.0	19.3	22.4	25.9	32.0
40	1.4	2.9	4.3	5.8	7.2	8.7	10.9	13.0	17.4	21.6	26.2	30.6	34.9	42.8
45	1.7	3.3	4.9	6.6	8.2	9.9	12.4	14.9	19.8	24.8	29.8	34.8	39.7	49.6
50	1.9	3.6	5.6	7.4	9.3	11.2	14.0	16.8	22.4	28.0	33.6	39.1	44.8	56.0
60	2.3	4.6	6.9	9.2	11.4	13.9	17.3	20.8	27.6	34.6	41.6	48.4	55.4	69.2
65	2.5	5.1	7.6	10.2	12.7	15.2	19.1	22.9	30.5	38.1	45.8	53.2	61.0	76.4
70	2.8	5.6	8.2	11.2	14.0	16.8	21.0	25.2	33.6	42.0	50.4	59.8	67.2	84.0
73	2.9	5.9	8.8	11.8	14.8	17.8	22.2	26.6	36.4	44.4	53.2	62.0	71.0	88.5
75	3.1	6.1	9.2	12.3	15.3	18.4	23.0	27.6	26.8	46.0	55.2	64.2	73.5	92.0
80	3.4	6.7	10.1	13.4	16.8	20.1	25.2	30.2	40.2	50.2	60.4	72.5	80.8	100.0
90	4.0	8.0	12.0	16.0	20.0	24.0	30.0	36.0	48.0	60.0	72.0	84.0	96.0	120.0
100	4.8	9.5	14.3	19.1	23.8	28.6	35.8	42.4	57.2	71.4	86.0	100.0	114.6	143.0
120	6.9	13.9	20.8	27.8	34.7	41.6	52.0	62.4	83.0	104.0	125.0	145.8	166.2	208.0
140	11.0	22.0	33.0	44.0	54.9	65.9	82.4	98.9	131.9	164.8	197.8	230.8	263.8	329.7

Suggested Minimum Spray Heights

Adjust the spray height to give proper spray overlap. The following table gives suggested minimum spray heights for several spray angles.

Suggested Minimum Spray Heights

Spray angle	20-inch spacing	30-inch spacing
65 degrees	22" to 24"	33" to 36"
73 degrees	20" to 22"	29" to 36"
80 degrees	17" to 19"	26" to 28"
110 degrees	10" to 12"	14" to 18"



PRESSURE DROP THROUGH SPRAYING SYSTEMS

Hoses and fittings must be selected in order to keep the pressure drops within acceptable limits. The following tables give the pressure drop through various size hoses, pipe, and couplings.

Pressure Drop for Water Flow through Various Hose Sizes

	Pressure drop in pounds per square inch (10-foot length--without couplings)								
Flow in GPM	1/4" I.D.	3/8" I.D.	7/16" I.D.	1/2" I.D	5/8" I.D	3/4" I.D.	1" I.D.	1 1/4" I.D.	1 1/2" I.D.
0.2	.3								
0.3	.6								
0.4	1.0								
0.5	1.4	.2							
0.5	2.0	.3							
0.8	3.3	.5							
1.0		.7	.3						
1.5		1.4	.6	.4					
2.0		2.4	1.1	.6					
2.5		3.4	1.7	.9					
3.0			2.4	1.2	.4				
4.0				2.0	.7				
5.0				2.9	1.0	.4			
6.0				4.0	1.4	.6			
8.0					2.6	.9	.3		
10					3.6	1.4	.4		
15						3.0	.8	.3	
20							1.4	.5	.2
25							2.0	.7	.3
30							2.8	.9	.4
40								1.6	.5
50								2.5	.8
60								3.4	1.2
70									1.6
80									2.0
90									2.6
100									3.0

NOTE: These figures are for standard hose in good, smooth condition (10-foot length with no couplings).

Flow of Water through Schedule 40 Steel Pipe

Flow in GPM	Pressure Drop in psi for Various Pipe Sizes (in 10-foot length) 1/8"	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
0.3	.42								
0.4	.70	.16							
0.5	1.1	.24							
0.6	1.5	.33							
0.8	2.5	.54	.13						
1.0	3.7	.83	.19	.06					
1.5	8.0	1.8	.40	.12					
2.0	13.4	3.0	.66	.21	.05				
2.5		4.5	1.0	.32	.08				
3.0		6.4	1.4	.43	.11				
4.0		11.1	2.4	.74	.18	.06			
5.0			3.7	1.1	.28	.08			
6.0			5.2	1.6	.38	.12			
8.0			9.1	2.8	.66	.20	.05		
10				4.2	1.0	.30	.08		
15					2.2	.64	.16	.08	
20					3.8	1.1	.28	.13	
25						1.7	.42	.19	.06
30						2.4	.59	.27	.08
35								.36	.11
40								.47	.14
45									.17
50									.20
60									.29
70									.38
80									.50
90									.62
100									.76

NOTE: These figures are for standard pipe of either seamless or welded construction, in good clean condition. Recommended maximum capacity to keep velocity at approximately 5 feet per second is shown above underlined value.

Approximate Friction Loss in Pipe Fittings in Terms of Equivalent Feet of Straight Pipe

Pipe size standard weight	Actual inside diameter inches	Gate value FULL OPEN	Globe value FULL OPEN	45 Elbow	Run or standard tee	Standard elbow or run of tee reduced 1/2	Standard tee through side outlet
1/8	.269	.1	8	.3	.4	.7	1.4
1/4	.364	.2	11	.5	.6	1.1	2.2
1/2	.622	.3	18	.7	1.1	1.7	3.3
3/4	.824	.4	23	.9	1.4	2.1	4.2
1	1.049	.5	29	1.2	1.8	2.6	5.3
1-1/4	1.380	.7	38	1.6	2.3	3.5	7.0
1-1/2	1.610	.8	45	1.9	2.7	4.1	8.1
2	2.067	1.1	58	2.4	3.5	5.2	10.4
2-1/2	2.469	1.3	69	2.9	4.2	6.2	12.4
3	3.068	1.6	86	3.6	5.2	7.7	15.5
4	4.026	2.1	113	4.7	6.8	10.2	20.3
5	5.047	2.7	142	5.9	8.5	12.7	25.4
6	6.065	3.2	170	7.1	10.2	15.3	31

NOZZLE WEAR LIFE

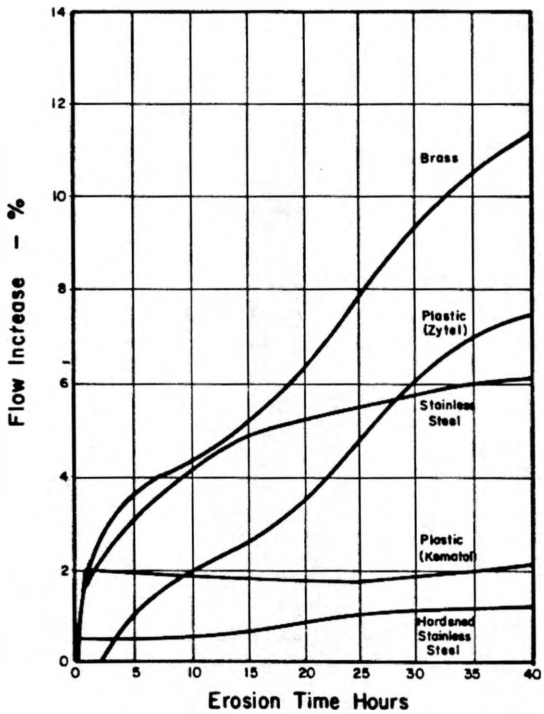
Nozzle tips are available in a variety of materials, including hardened stainless steel, stainless steel, thermoplastics, and brass. Hardened stainless steel is the most wear-resistant material, but it is also the most expensive. Stainless steel tips have excellent wear resistance with either corrosive or abrasive materials. Nylon and other synthetic plastics (thermoplastics) are resistant to corrosion and abrasion but they vary considerably in their wear life, depending on the material used to mold the tips. Brass tips wear rapidly when used to apply abrasive materials such as wettable powders and they are corroded by some liquid fertilizers.

The following figure shows the wear rates of a flat-fan nozzle constructed of various materials. The data was based on testing with 25 pounds kaolin clay in 50 gallons of water at 40 psi.

NOZZLE WEAR TEST
for Flat Fan Nozzle Tip #4

This data was based on 40 hours of testing with 25 lbs (10.75 k) kaolin clay in 50 gallons (189 liters) of water at 40 psig (275 kPa)

Comparison of % of Wear (Flow Increase) vs Erosion Time



MISCELLANEOUS REFERENCE INFORMATION

Standard Abbreviations

GPA---Gallons per Acre
GPM---Gallons per Minute
GPH---Gallons per Hour
MPH---Miles per Hour
OPM---Ounces per Minute
PSI---Pounds per Square Inch (gauge pressure)

Useful Formulas

$$\text{GPM (Per Nozzle)} = \frac{\text{GPA X MPH X W*}}{5940}$$

$$\text{GPA} = \frac{\text{5940 X GPM (Per Nozzle)}}{\text{MPH x W*}}$$

*W = Nozzle spacing (in boom spraying) or spray swath (in boomless spraying)...in inches.

Volume and Liquid Measures

8 fluid ounces = 16 tablespoons = 1 cup = 236.6
2 cups = 32 tablespoons = 1 pint = 473.1 ml
2 pints = 64 tablespoons = 1 quart = 946.2 ml
4 quarts = 256 tablespoons = 1 gallon = 3785 ml
128 fluid ounces = 1 gallon = 3785 ml

Miscellaneous Conversion Factors

One Acre = 43,560 squre feet = 0.405 Hectares.
One Hectare = 2.471 Acres.
One Gallon Per Acre = 9.35 Liters Per Hectare.
One Mile = 5,280 feet = 1610 Meters = 1.61 Kilometers.
One Gallon = 128 fluid ounces = 8 pints = 4 quarts = 3.79 Liters = 0.83 Imperial Gallons.
One Pound Per Square Inch (PSI) = 0.070 kg/cm^2 = 6.895 kPa (Kilopascal)
One Pound = .454 Kilogram.
One Inch = 2.54 Centimeters.

Metric Conversion Factors

During the next few years, a gradual transition to metric (SI) units is expected in the agricultural industry. To facilitate use of these units, the following metric terms and conversion factors are provided.

To measure	Multiply	By	To obtain
	inches	25.40	millimeters (mm)
LENGTH	inches	2.540	centimeters (cm)
	feet	0.3048	meters (m)
	miles	1.609	kilometers (km)
AREA	acres	46.7	square meters (m^2)
	acres	0.4047	hectares (ha)
VOLUME	gallons	3.785	cubic decimeters (dm^3)
	gallons	3.785	liters (L)
	Imperial gallons	4.546	liters (L)
FLOW RATE	gallons/hours (gph)	3.785	liters/hour (L/h)
	gallons/minute (gpm)	3.785	liters/minute (L/min)
APPL. RATE	gallons/acre (gpa)	9.353	liters/hectare (L/ha)
PRESSURE	pounds per square inch (psi)		
SPEED	miles/hour (mph)	6.895	kilopascals (kPa)
		1.609	kilometers/hour (km/h)

The Illinois Agrichemical Facility Containment Program

W. Goetsch and V. Thompson

January 1, 1990, marks the beginning of a new program for the agrichemical industry and the Illinois Department of Agriculture (IDOA). This program includes many requirements for the handling and storage of agrichemicals, containment strategies for both operational areas and storage areas, facility registration and permitting requirements, as well as water source protection and open burning restrictions. These rules resulted from a great deal of work by industry, government, and university people attempting to draft a set of rules that would not place an unduly restrictive burden on the industry while adequately ensuring the protection of Illinois's groundwater. It is estimated that 1,500 sites will be affected by these new rules.

The program will be divided into three time periods: registration, planning and permit application, and construction. All sites will register with the Department between January 1 and April 1, 1990. Individual compliance schedules will be generated and forwarded to facilities by July 1, 1990, based on information received during the registration period. Facilities will have between one and three years to develop plans and apply for permits for construction of needed environmental protection facilities. The time period will be based on the amount of existing environmental protection containment that a facility has when the rules go into effect. Construction plans and permit applications will be reviewed jointly by IDOA and the Illinois Environmental Protection Agency, with IDOA issuing construction and operating permits. The construction phase will begin when the planning and permitting applications have been approved. Again, facilities will have various time periods to complete construction depending upon the amount of containment facilities that were in existence as of January 1, 1990.

IDOA, as a part of this program, will be collecting groundwater samples from various facilities that utilize well-water sources. These samples will be analyzed for pesticide contamination to help establish benchmark or background levels of groundwater quality associated with agrichemical sites. A staff of four field inspectors and a department program manager will provide initial manpower for the program, augmented by other existing departmental staff as needed. All records will be computerized for report generation, program management, and general data management. In general, the program is an initial approach to the protection of Illinois groundwater from point source contamination by agrichemicals.

A summary of bulk containment rules that become effective January 1, 1990, follows. The rules are administered by the Illinois Department of Agriculture under Title 8, Chapter 1, Subchapter i, Part 255, Agrichemical Facilities.

This summary only highlights the requirements and contents of Part 255 and is not intended as a substitute for the complete rules. The published rules must be referred to for definitions, details, and specific compliance requirements.

Section 255.30 SCOPE AND APPLICATION. The rules apply to existing and new agrichemical facilities and noncommercial agrichemical facilities where agrichemicals are handled in quantities exceeding the thresholds defined. The rules do not apply to field mixing and some temporary loading sites.

1) Agrichemical facility: a commercial site where bulk pesticides are stored more than 30 days in a single container in quantities greater than 300 gallons liquid or 300 pounds dry; or where pesticide quantities greater than 300 gallons liquid or 300 pounds dry (bulk or packaged) are being mixed, repackaged, or transferred between containers within a 30-day period; or where bulk fertilizers are stored, mixed, repackaged, or transferred between containers (no minimum quantities for fertilizer).

2) Noncommercial agrichemical facility: a user site (such as a farm) used for *each of the following situations*: 1) where bulk pesticides in excess of 300 gallons liquid or 300 pounds dry, or bulk fertilizer in excess of 5,000 gallons liquid or 50,000 pounds dry, are stored in a single container more than 45 days; 2) where quantities greater than any of the above (packaged or bulk) are loaded, mixed, or repackaged at a permanent site for more than a 45-day period; and 3) noncommercial application of pesticides or fertilizer.

Section 255.40 REGISTRATION. Agrichemical facilities that fall within the above definition must register with the Department of Agriculture by April 1, 1990. Registration will be on forms furnished by the Department and will define the scope of existing operations and facilities. Registration establishes one or more of seven conditions relative to storage containers, containment, and operations existing at a facility. Compliance times for the various situations differ and are based on potential pollution risk and containment already installed.

Section 255.50 PERMITS AND COMPLIANCE SCHEDULE. An agrichemical facility permit must be completed for each facility. Department approval is required prior to construction or future modification of containment systems. The permit requirements include application forms, engineering plans, and specifications. Acceptable permit applications will be approved within 90 days.

A registered professional engineer, when required by the Illinois Professional Engineering Act, must prepare the plans and specifications. The Department's interpretation is that a facility owner or permanent employee may prepare the application including plans and specifications without the services of a registered professional engineer. The owner may utilize design criteria, specifications, and other guidance provided by professional engineering services as reference materials for developing plans and specifications for his own facility.

Permit application and compliance schedules vary with conditions that exist at a facility upon registration. These schedules are summarized in Table 1; they show requirements for obtaining permits and completing containment installation.

Section 255.60 EXPERIMENTAL PERMITS. This section provides means and a trial period to utilize and prove new technology without certifying that environmental protection will be equal to protection provided by the regulations.

Innovative design provided for in Section 255.50, c, requires that protection of the environment be at least equivalent to protection dictated by the rules.

<u>Section 255.70 AGRICHEMICAL FACILITY PLANS, SPECIFICATIONS, AND RECORDS</u>. This section lists records and other information that must be maintained at the facility and available for inspection. These items include plot plans, tank schedules, secondary and operational containment construction plans, operational plans for containment and recovery systems, chemical producers' storage and handling instructions for pesticides, spill reports, state inspection reports, and facility inspection and maintenance reports.

<u>Section 255.80 SECONDARY CONTAINMENT</u>. All agrichemical nonmobile storage containers for liquid pesticides and liquid fertilizer must be located within a secondary containment structure. Containment capacity must provide for 100 percent of the largest tank if located inside or an additional freeboard capacity to provide for a 6-inch rain if located outside, exposed to the elements.

Structure requirements are performance-based, requiring a floor or barrier under all tanks and walls, both with specified permeability levels. Construction materials must be compatible with the products stored. Synthetic liners/basins/materials will require written confirmation of compatibility and estimated life. Earthen/clay containment structures are allowed for fertilizer, but prohibited for pesticides. The earthen/clay liners must be at least 12 inches thick.

Secondary containment structures must not have a discharge outlet or gravity drain through the wall or floor. Pipes are not allowed to pass through containment walls. Pesticides and fertilizers should be separated.

Mini-bulk containers filled and warehoused for distribution will require secondary containment equal to the volume of the largest container or an immediate spill response action plan. This is the only requirement for warehouse containment (Sec. 255.80, d).

<u>Section 255.90 OPERATIONAL AREA CONTAINMENT</u>. Operational areas at a facility site are defined as areas where agrichemicals are loaded, unloaded, mixed, repackaged, or cleaned and washed from application or other equipment. Operational area containment structures or systems must be designed to intercept, retain, and allow recovery of spillage, wash water, and other residues containing agrichemicals, and to prevent material from reaching the site soil.

Loading areas: These areas require a containment system to catch, retain, and recover spillage. Minimum containment volume is equal to the largest tank loaded or, if located outside, the volume to contain a 6-inch rain. Aboveground tank(s) and an automatic sump pump system can be used to satisfy volume requirements.

Unloading areas: Loading area containment can be used for unloading, or individual catchment basins or portable containers with a minimum capacity of 25 gallons can be used to catch and recover spillage/leakage from transfer connections and pumps.

Mixing and repackaging areas: Curbs or basins to catch and retain spillage for recovery are required. No minimum volumes are required.

Cleaning and washing areas: All cleaning and washing of agrichemical residues from equipment at the facility site must be done within a containment system. No minimum volumes are required, but the system must be capable of intercepting and retaining wash water to allow recovery.

Transfer structures and systems: Underground tanks and structures cannot be used for "storage" of rinsates, wash water, or other agrichemical residues. Sumps and wet wells must not have material left in them longer than 72 hours (retention time). Scale pits and other underground structures must be sealed to prevent leakage. Note: Regulatory emphasis on underground containers dictates close management for continued utilization of these structures to prevent their being defined as underground tanks.

Section 255.100 STORAGE CONTAINERS AND APPURTENANCES. This section is self-explanatory. In most cases, existing tanks and appurtenances will be acceptable. Valves on storage tanks and some mobile tanks require locks to comply with security provisions. External sight gauges are not allowed on bulk pesticide tanks, and, where used on liquid fertilizer tanks, the bottom valve must be locked. Storage tank flotation resulting from liquid accumulation in secondary containment structures must be prevented. Anchoring or raised platforms may be needed where calculations indicate potential for flotation. Note: Anchors should be considered in secondary containment design.

Section 255.110 CONTAINMENT MANAGEMENT AND OPERATIONS. Management and operational practices associated with containment systems are covered in this section. It covers handling precipitation accumulation, spills, agrichemical residues, rinsates, and pesticide containers with provisions for reuse and disposal.

Provisions are made for discharge of uncontaminated precipitation accumulation as surface runoff. The rules recommend and specify cleaning methods and practices. Field application of agrichemical residues, rinsates, contaminated wash water, and diluted pesticide mixtures in accordance with the pesticide label(s) is allowed.

Field washing the exterior of application equipment is an acceptable practice. Covering hoppers combined with field cleaning by brushing is an acceptable cleaning method for dry application equipment. Application equipment that is not clean must be parked on operational containment areas or under roof.

Pesticide containers must be triple or pressure rinsed and stored in operational containment or protected from precipitation. The rules require immediate spill cleanup and reporting of unrecovered spills. Pesticide containers and unusable pesticides or mixtures must be disposed of in accordance with waste regulations.

Section 255.120 SITE CLOSURES AND DISCONTINUATION OF OPERATIONS. All agrichemicals and agrichemical containers must be removed from a closed agrichemical facility site and reused or properly disposed. (Note: The intent is removal of agrichemicals from nonmobile containers and removal of mobile agrichemical containers.)

Section 255.130 INSPECTION AND MAINTENANCE. Weekly inspection of storage containers and secondary containment structures must be made and written records maintained. Monthly inventory of liquid storage tanks containing product is required.

Section 255.140 DRY FERTILIZER STORAGE AND HANDLING. Dry fertilizer must be stored inside a building, or under cover with sidewalls and a base sufficient to prevent contact with precipitation. All handling is to be done in a manner to prevent pollution and to minimize losses to air, surface water, groundwater, and subsoil. Methods for containment or structures for handling and mixing areas are required. Five suggested methods of containment are provided in 255.240, d.

Section 255.150 DRY FERTILIZER BLENDING OPERATIONS. Blending and impregnation operations must provide for dust and vapor control and for total collection and reuse of spilled materials. Impregnation of dry fertilizer with pesticides will require operational containment with provisions to contain and recover contaminated water in the blending and loading operations.

Section 255.160 CONNECTIONS TO THE POTABLE WATER SUPPLY. Proper backflow protection for public and private water supply systems is required. Protection, installation, and maintenance must be in compliance with listed Illinois codes. Backflow protection will require a "reduced pressure principle backflow preventer" or a fixed proper air gap (break-tank).

Section 255.170 OPEN BURNING. Open burning of agrichemical containers and related pesticide wastes will be allowed under specific conditions at some agrichemical facilities and noncommercial agrichemical facilities. The rules must be referred to for the specific conditions under which open burning can be conducted. Open burning of these materials is also permissible at the field where the chemicals are applied under certain specified conditions.

The approved incinerator for disposal discussed (Section 255.170, b) is not economically feasible for an individual agrichemical facility with current technology and design operating conditions. Compliance here means that the incinerator is designed and operated under IEPA air permit regulations. Open burning at an agrichemical facility will not be allowed after January 2, 1995.

TECHNICAL STANDARDS: WELL SETBACK ZONES AND REGULATED RECHARGE AREAS

The Illinois Groundwater Protection Act established protection zones around public and private wells and mandated that technical controls be established for certain activities located within these setback zones. Pesticide and fertilizer storage and handling facilities are identified as secondary sources of potential well contamination and their activities must be regulated.

Future regulations will impose additional requirements on existing agrichemical facilities located within minimum setback zones and any expanded setback zone or regulated recharge area defined in the future. The requirements may include quarterly groundwater monitoring for pesticides and nitrates and corrective action programs if contamination ever exceeds the yet-to-be-established groundwater standards. There will also be reporting requirements to IEPA on monitoring and other record keeping.

The minimum setback zone from any off-site private or public well will be 200 feet, 400 feet for community wells in susceptible aquifer areas. The setback zone may be expanded to 1,000 feet if a community can justify the need and up to 2,500 feet for regulated recharge areas. *All agrichemical facilities should evaluate their setback zone status.*

Table 1. Compliance Schedule for Agrichemical Facilities Containment Program Based on Existing Operational Area and Secondary Containment Structures

If the facility has:	The compliance schedule is:		
	Submit permit application plans and specifications	Complete operational containment construction	Complete secondary containment construction
1. No operational area containment or secondary containment	1 year	2 years	3 years for liquid pesticide; 4 years for liquid fertilizer
2. Secondary containment only	2 years	3 years	4 years
3. Operational area containment only/or IEPA permit	2 years	5 years	3 years for liquid pesticide; 4 years for liquid fertilizer
4. Both operational containment and secondary containment	2 years	5 years	5 years
5. 100,000-gallon-or-more fertilizer tank (notice to comply by 4 years)	5 years	N/A	7 1/2 years

6. Dry bulk fertilizer storage must be in compliance in 5 years.

7. Dry bulk fertilizer blending must be in compliance in 5 years.

8. Noncommercial facilities must be in compliance in 5 years.

Restricted-Use Pesticides

P. Nixon

In 1972, amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provided the legal mechanism for restricting the use of certain pesticides. The U.S. Environmental Protection Agency (EPA), confronted with the enormous task of reviewing all registered pesticides, proposed to classify pesticides by their active ingredient, subdividing each active ingredient into its various formulations or uses. This classification system provided the EPA with more flexibility to restrict some, but not all, products containing the same active ingredient. The process was called classification by regulation. When pesticides are restricted in this manner, the manufacturer is given 270 days to amend the label on all the affected products. This timetable has been of particular interest to pesticide dealers because once the restricted-use label is applied to the container, it can be sold only to a certified applicator.

In addition to reviewing existing products, the EPA is required to register new products not previously marketed. Some of these new products have been classified for restricted use. This process is called classification by registration.

Pesticides classified for restricted use by registration and regulations are listed in Table 1.

Table 1. Restricted-Use Pesticides (September 1989)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
alachlor	Lasso, others	herbicide	all formulations	oncogenicity
aldicarb	Temik	insecticide-nematicide	all formulations	accident history
aluminum phosphide	Phostoxin, Detia, many others	fumigant	all formulations	human inhalation hazard
amitrol	Weedazol, Amizol, others	herbicide	all except homeowners	possible oncogenicity
arsenic acid	Desiccant, Zotox	herbicide	all formulations	oral toxicity, oncogenicity
arsenic pentoxide	many	wood preservative	all formulations	oncogenic, mutagenic, reproductive, fetotoxic effects
arsenic trioxide	white arsenic	wood preservative	all formulations except brush-on	oral toxicity; oncogenicity; mutagenicity; reproductive and fetotoxic effects
avitrol	Avitrol	avicide	all formulations	hazard to fish and nontarget birds
azinphosmethyl	Guthion, many others	insecticide	all liquids with concentrations above 13.5%	human inhalation toxicity; acute toxicity hazard to avian, aquatic, and mammalian species
bromoxynil	Buctril, others	herbicide	all formulations	teratogenicity
cadmium chloride	Vi-Cad, Caddy	fungicide	power sprayer	kidney effects
calcium cyanide	A-Dust	fumigant	all formulations	human inhalation hazard
carbofuran	Furadan	insecticide-nematicide	concentrate suspension and wettable powders; all granular formulations	acute inhalation toxicity
carbon tetrachloride	carbon tetrachloride	fumigant	liquid	oncogenicity, poisoning risks
chlordimeform	Galecron, others	insecticide	all formulations	causes cancer in laboratory animals
chlorfenvinphos	Birlane, others	insecticide	formulations greater than 21%	acute dermal toxicity

Table 1. (continued)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
chlorobenzilate	Acaraben, others	insecticide	all formulations	oncogenicity
chlorophacinone	Rozol Blue Tracking Powder	rodenticide	all formulations	human hazard, potential for food contamination
chloropicrin	many	fumigant	all formulations	acute inhalation toxicity; hazard to nontarget organisms
chlorpyrifos	Killmaster II	insecticide	Killmaster II	------------------------
chromic acid	-----------	wood preservative	all formulations except brush-on	oncogenicity; mutagenicity; teratogenicity; fetotoxic effects
creosote, creosote oil, coal tar creosote	many	wood preservative	all formulations	possible oncogenic and mutagenic effects
cyanazine	Bladex, Extrazine II	herbicide	all formulations	groundwater contamination, teratogenicity, fetotoxicity
cyfluthrin	Baythroid	insecticide	25% EC agricultural uses	toxic to applicator, toxic to fish and other aquatic organisms
cypermethrin	Cymbush, Ammo, others	insecticide	all formulations	oncogenicity, hazard to non-target organisms
diallate	Avadex	herbicide	only product	oncogenicity, mutagenicity
dichloropropene	Telone	fumigant	94% liquid concentrate	possible oncogenicity, acute toxicity
diclofop methyl	Hoelon	herbicide	all formulations	oncogenicity
dicrotophos	Bidrin, others	insecticide	all liquid formulations	acute dermal toxicity, residue effects on birds
diflubenzuron	Dimilin	insecticide	all formulations except cattle bolus	lack of environmental hazard data
dioxathion	Delnav, Deltic	insecticide	formulations greater than 30%	acute dermal toxicity
disulfoton	Di-Syston	insecticide	some emulsifiable concentrates	acute dermal and inhalation toxicity

Table 1. (continued)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
dodemorph	Milban	fungicide	all formulations	corrosive to eye tissue
endrin	Endrin, many others	insecticide	all formulations	acute dermal toxicity, hazard to nontarget organisms
esfenvalerate	Asana	insecticide	all formulations	high fish toxicity
ethion	Ethion	insecticide, miticide	8EC	registration action
ethoprop	Mocap	insecticide	all formulations	acute dermal toxicity
ethyl parathion	Parathion, many	insecticide	all formulations	acute dermal and inhalation toxicity, effects on birds, fish, and mammals
fenamiphos	Nemacur	nematicide	emulsifiable concentrates	acute dermal toxicity
fenitrothion	Sumithion, others	insecticide, acaricide	-----------------	potential hazard to birds and aquatic organisms
fensulfothion	Dasanit	insecticide	emulsifiable concentrates and solutions, all granular formulations	acute dermal and inhalation toxicity
fenvalerate	Pydrin	insecticide	emulsifiable concentrates, except ear tags, Ectrin WDL	high fish toxicity
flucythrinate	Pay-Off	insecticide	all formulations	possible adverse effects on aquatic organisms
fluoroacetamide	1081, others	rodenticide	all formulations	acute oral toxicity
fluvalinate	Mavrik	insecticide	emulsifiable concentrate and flowable concentrate at 2 lb/gal	toxicity to aquatic organisms
fonofos	Dyfonate	insecticide	all liquid formulations, granular formulations greater than or equal to 20%	acute dermal toxicity
isazofos	Triumph, Brace	insecticide	all formulations	avian, fish, and aquatic organism toxicity
isofenphos	Pryfon	insecticide	65% liquid formulation	acute toxicity

Table 1. (continued)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
lambda-cyhalothrin	Karate	insecticide	all formulations	toxicity to fish and aquatic invertebrates
lindane	many	insecticide	all liquid formulations	possible oncogenicity
magnesium phosphide	Fumi-Cel, Detia	fumigant	all formulations	acute inhalation toxicity
methamidophos	Monitor	insecticide	liquid formulations 40% or greater; dust formulations 2.5% or greater	acute dermal toxicity, residue effects on birds
methidathion	Supracide	insecticide	all formulations	residue effects on birds
methiocarb	Mesurol	bird repellent	dusts, hopper box treater	possible hazard to avian, fish, and wildlife species
methomyl	Lannate, Nudrin	insecticide	all concentrated solution formulations	residue effects on mammals, accident history
methyl bromide	many	fumigant	all formulations in containers heavier than 1.5 pounds	accident history, acute inhalation toxicity
methyl parathion	many; Penncap-M	insecticide	all formulations	acute dermal toxicity, residue effects on birds, bees, and mammals
mevinphos	Phosdrin, others	insecticide	all formulations	acute dermal toxicity, residue effects on birds and mammals; acute dermal toxicity
monocrotophos	Azodrin, others	insecticide	liquid formulations	residue effects on birds and mammals; acute dermal toxicity
nicotine (alkaloid)	Black Leaf 40	insecticide	all formulations	acute inhalation toxicity, effects on aquatics
oxamyl	Vydate	insecticide, nematicide	all formulations	acute oral and inhalation toxicity
oxydemeton-methyl	Metasystox-R	insecticide	all formulations	reproductive effects
paraquat dichloride paraquat bis (methylsulfate)	Gramoxone	herbicide	all formulations	use and accident history

Table 1. (continued)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
pentachlorophenol	Penta wood preservative; many others	wood preservative	all formulations	possible oncogenic, teratogenic and fetotoxic effects
permethrin	Ambush, Pounce	insecticide	all formulations, excluding livestock and premise use	high fish toxicity
phorate	Thimet, Phorate	insecticide	all liquid and granular formulations	acute dermal toxicity, residue effects on birds and mammals
phosacetim	-------------	----------	all baits 0.1% and greater	Hazard to nontarget organisms; residue effects on birds and mammals
phosphamidon	Dimecron, others	insecticide	all formulations	acute dermal toxicity, residue effects on birds and mammals
picloram	Tordon, others	herbicide	all formulations except Tordon 101R and Tordon ready-to-use	hazard to nontarget plants; persistence and leachability
potassium pentachlorophenate	Permatox 182	herbicide	all formulations	oncogenicity, mutagenicity, fetotoxicity
PP321	----------	----------	all formulations	toxic to fish and aquatic invertebrates
profenofos	Curacron, Selecron, Polycron	insecticide, acaricide	emulsifiable concentrates	corrosive to eyes
pronamide	Kerb	herbicide	all 50% wettable powders	special review
propetamphos	Safrotin	insecticide	only product	voluntary restriction
sodium cyanide	Cymag	fumigant	all formulations	human inhalation toxicity
sodium dichromate	------	wood preservative	all formulations except brush-on	oncogenicity; mutagenicity; teratogenicity, fetotoxicity
sodium fluoroacetate	1080	rodenticide	all formulations	acute oral toxicity, use and accident history; hazard to nontarget organisms

Table 1. (continued)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
sodium pyroarsenate	--------	wood preservative	all formulations except brush-on	oral toxicity; oncogenicity mutagenicity; reproductive and fetotoxic effects
starlicide	Gull-Toxicant 98% Concentrate	bird repellent	only product	hazard to nontarget organisms
strychnine	many	rodenticide	all formulations greater than 0.5%	acute oral toxicity, effects on nontarget organisms, accident history
sulfotep	Bladafum	fumigant	all formulations	acute inhalation toxicity
sulfuric acid	Asarco	herbicide	potato vine desiccant	extremely corrosive; acute toxicity to humans
sulfuryl fluoride	Vikane	fumigant	all formulations	acute inhalation hazard
sulprofos	Bolstar	insecticide	all formulations	wildlife hazard
tefluthrin	Force	insecticide	all formulations	fish toxicity
terbufos	Counter	insecticide	all formulations	effects on nontarget organisms
tralomethrin	Scout	insecticide	emulsifiable concentrate formulations	toxicity to aquatic organisms
triphenyltin hydroxide	TPTH, others	fungicide	all formulations	possible mutagenic effects
zinc phosphide	many	rodenticide	all formulations	acute oral and inhalation toxicity, hazard to nontarget organisms

Suggestions for Minimizing Bee, Fish, and Wildlife Losses from Pesticides

G. Sanderson, P. Tazik, E. Killion, and K. Steffey

It may be impossible to use pesticides without endangering some nontarget species. However, through prudent use, pesticide hazards to fish and wildlife can be substantially reduced. Here are some precautions to follow:

1. Apply pesticides according to the instructions given by the manufacturer and the Cooperative Extension Service.

2. If more than one pesticide is available to control a specific pest, use the pesticide least toxic to nontarget organisms.

3. Avoid drift if at all possible.

4. Follow instructions in disposing of pesticide containers.

5. In wildlife and aquatic areas, use ground equipment so that pesticides can be confined to specific target areas.

6. Make sure that pesticide-treated seed is not readily available to birds or mammals.

7. For application to water, use only those pesticides registered by the federal EPA for aquatic use (Rule 203h, Water Pollution Regulations, as amended).

8. If a pesticide is extremely toxic to fishes, avoid applying it in the immediate watershed, including ditches and channels that drain into bodies of water.

9. Wash application equipment properly, and do not permit wash water to contaminate any body of water.

SOME CHARACTERISTICS OF ANIMAL POPULATIONS IN ILLINOIS THAT ARE HELPFUL IN UNDERSTANDING THE WILDLIFE-PESTICIDE PROBLEM

First, it should be emphasized that there is still a great deal to learn about the overall effects of any pesticide on any population of vertebrate animals in the wild. Certain general facts have been established, however. Considerable data are available on the acute toxicity of various compounds to a variety of species in captivity. Also, there are a limited number of studies of population recovery rates after one or more applications of a pesticide to an area. Some pesticides may cause high mortality in populations of wild vertebrates both directly and indirectly through the food chain. It has been shown that persistent chemicals, such as the chlorinated hydrocarbons, are concentrated from the bottom to the top of the food chain. Animals at the top of the food chain often accumulate heavy dosages of the toxin, and as a result, whole populations may lose their reproductive capacity. Accumulations of organo-chloro insecticides through the food chain, for example, may have reduced the reproductive capacity of the bald eagle, duck hawk, and other raptor populations both in Europe and North America. The reproductive capacity of certain species of fishes and fish-eating birds, such as loons, cormorants, and pelicans, may have been reduced as well.

Although this discussion refers to all wild vertebrates, most of the remarks and examples refer to birds. Because of their migratory and highly mobile nature, birds are more susceptible to poisoning in large numbers from a single application of pesticide.

The simpler the habitat, the fewer organisms it supports, in terms of the variety or diversity of organisms. Conversely, the more complex the habitat, the greater the number and variety of organisms. For example, in summer, bare plowed ground usually supports only about three to five native species of birds with only about one bird for every two acres. At the other extreme is a forest, which supports about eighty to eighty-five nesting species of birds with about five to eight birds per acre. Of the agricultural habitats in Illinois, corn and soybean fields have the lowest bird populations, essentially the same as plowed bare ground; wheat fields support only slightly higher numbers; and oat fields have conspicuously higher bird populations. Grasslands and hayfields are very rich bird habitats, with forty to seventy native species in the summer and three to five birds per acre. The shrub borders and hedges at the edges of cultivated fields have some of the densest populations of birds of any Illinois habitat. Marshlands also have high populations and many species. In Illinois, the prairie-grassland and marsh-dwelling species are in greatest danger, declining to dangerously low population levels.

Regrettably, the effects of pesticides applied to a field may not stop at the borders of that field. Animals, especially birds, from adjacent fields may pass through a pesticide-treated field or forage at its boundaries. A 1964 study in Illinois indicated that in a single breeding season two successive populations of birds in a hayfield were killed from the effects of one application of 1/4 pound of dieldrin on a nearby wheatfield. The hayfield had not been sprayed, but the birds there were dead. A third population of birds that moved into the hayfield within a month of the spray date was unable to produce fertile eggs.

Populations of birds shift greatly from season to season. Between April 15 and June 10, and again between September 1 and November 15, the bird populations in all parts of Illinois reach their greatest numbers. More than 200 species are present in the state, and their numbers are many times greater than the normal breeding populations. Many of these species are insectivorous. After October 1, increasing numbers of waterfowl appear in the wetlands of the state. The songbird populations penetrate every habitat, but they are most abundant where there is some woody vegetation. Populations of songbird migrants in open habitats probably reach their peaks in late March to mid-May and again in October and early November. Fortunately, most of the migrants do not spend time in plowed fields or in corn and bean fields, that is, in bare fields. An exception is the golden plover, thousands of which pass through the state in April and May; these birds regularly feed in bare fields and grasslands and concentrate particularly around rain pools.

In Illinois, bird populations reach their lowest levels in the northern third of the state in the winter (January 1 to March 1), but in the southern third of the state, winter populations are even higher than the summer populations in practically all habitats.

FACTS ABOUT PESTICIDES AND FISH MORTALITY

Fish kills in ponds and streams can be caused by a number of factors, including runoff from fields treated with insecticides, herbicides, and fertilizers; improper application of aquatic pesticides; and other reasons not related to pesticide use. Insecticides and herbicides that enter water systems can be very toxic to fish. Thus, pesticides should be applied carefully in areas near ponds, lakes, or streams. Precautions should be taken to prevent pesticide drift from the target area and runoff from pesticide-treated fields.

Even chemicals registered for use in aquatic systems can cause fish kills when applied improperly or carelessly. When applying chemicals registered for use in aquatic systems, follow label directions and take precautions to avoid drift of the chemical into nontarget areas. It is especially important to be cautious when applying chemicals in drainage ditches, streams, or canals, where the water in the application area is moving to another area even during application. Fish and other organisms may be killed as the toxic agent flows downstream.

Table 1 shows comparative fish toxicities of some agricultural insecticides used in Illinois. The toxicity of a compound is expressed as an LC_{50}, the concentration of a pesticide, expressed in milligrams of pesticide per liter of water (mg/L, or parts per million), needed to kill 50 percent of the test fish in an aquarium during a 96-hour period. The LC_{50} value indicates only those fish killed immediately after exposure, not delayed mortality caused by compounds in fish fat reserves. Most of the toxicity values we have used are printed in the 8th edition of *The Pesticide Manual: A World Compendium* published in 1987 by the British Crop Protection Council (Lavenham Press Ltd.). A few of the values were taken from the *Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates* published in 1980 by the United States Department of the Interior, Fish and Wildlife Service. When the data were available, we used toxicity values for rainbow trout and bluegill, the two most common species used in toxicity trials.

Stability, storage in fat tissue, affinity, and solubility are chemical characteristics that should be considered when choosing chemicals. Stability is the length of time the chemical remains in a particular form in the environment. Stable compounds remain in the environment for longer periods of time than compounds more readily broken down. Compounds readily stored in fat could theoretically cause fish mortality after initial exposure if, under stress, the fat is suddenly used and the pesticides are redistributed throughout the fish's system. High affinity for soil particles means that the pesticide adheres to the soil rather than being readily removed and relocated to a nontarget area. Highly soluble chemicals dissolve readily in water. The more soluble a chemical is, the more quickly it may enter nearby water resources.

SOME FACTS ABOUT PESTICIDES AND BEES

Bees are highly important as pollinators of apples, pumpkins, clovers, cantaloupes, watermelons, blueberries, cucumbers, squash, and other crops in Illinois. Honey bees visit blooming soybeans in all areas of the state and improve yields of some varieties. The bees also visit sweet corn and field corn tassels when they are shedding pollen. Applicators should consider the bees' presence before applying insecticides during soybean bloom and when corn is pollinating. Highly poisonous to bees of all kinds, some common insecticides may cause serious losses to social bees, such as honey bees and bumble bees, as well as to the less-known solitary bees, such as alkali bees and leaf cutter bees.

Efficient management of pest control programs and of bees can do much to reduce the loss of bees through necessary agricultural pest-control operations. Relating spraying operations to daily bee activity, insecticide toxicity, plant maturity, and the potential for spray drift will reduce bee losses and may mean the difference between a satisfied producer and one faced with a lawsuit.

The toxicity of insecticides to bees can be drastically modified by abnormal weather conditions. Unusually low temperatures that occur after an application can cause insecticide residues on crops to remain toxic to bees up to 20 times longer than these residues would be toxic during reasonably warm weather. Also, if abnormally high temperatures occur during late evening or early morning, bees may actively forage on treated crops during these times when bees are *usually* less active.

RELATIVE TOXICITY OF PESTICIDES TO HONEY BEES

Pesticides differ greatly in their effects on honey bees. The formulation of the pesticide also plays an important role in its toxicity to bees. In general, sprays are safer than dusts, and emulsifiable concentrates are less toxic than wettable powders. Granular materials usually are not hazardous to bees. Microencapsulated formulations of highly toxic materials are extremely hazardous to bees. Penncap-M should not be used on crops visited by bees or in locations where it may contaminate other blooming crops or weeds. Fungicides, acaricides (miticides), herbicides, defoliants, desiccants, nematicides, and blossom thinners are relatively nontoxic.

Pesticides can be placed in three groups in relation to their effects on bees: highly toxic, moderately toxic, and relatively nontoxic.

HIGHLY TOXIC MATERIALS

This group includes materials that kill bees on contact during application and for one or more days after treatment. Bees should be moved from the area if highly toxic materials are used on plants the bees are visiting.

Pesticides (trade names and common names)

Aldrin
Ambush, permethrin (honey bee repellent)
Ammo, cypermethrin
arsenicals
Asana, esfenvalerate
Azodrin, monocrotophos
Baygon, propoxur
Baytex, fenthion
Baythroid, cyfluthrin
Cygon, dimethoate
Cymbush, cypermethrin
Cythion, malathion
Dasanit, fensulfothion
DDVP, dichlorvos
De-Fend, dimethoate
Dibrom, naled*
Dimecron, phosphamidon
Dursban, chlorpyrifos
D-Z-N, diazinon
EPN
Furadan, carbofuran

Pesticides (trade names and common names), continued

Gardona, tetrachlorvinphos
Guthion azinphos-methyl
heptachlor
Imidan, phosmet
Lannate, methomyl
Lorsban 4E, chlorpyrifos
malathion
Mesurol, methiocarb
methyl parathion
miral, Triumph
Monitor, methamidophos
Nemacur, fenamiphos
Nudrin, methomyl
Orthene, acephate
parathion
Penncap-M (micro-encapsulated methyl parathion)
Phosdrin, mevinphos*
Pounce, permethrin (honey bee repellent)
Pydrin, fenvalerate
Resmethrin
Sevin, carbaryl
Spectracide, diazinon
Supracide, methidathion
Synthrin, resmethrin
Tamaron, methamidophos
Temik, aldicarb
Vapona, dichlorvos
Zectran, mexacarbate

---

*Short residual activity. Can usually be applied safely when bees are not in flight. Do not apply over hives.

MODERATELY TOXIC MATERIALS

These materials can be used with limited damage to bees if not applied over bees in the field or at the hives. Correct dosage, timing, and method of application are essential.

Insecticides (trade names and common names)

Abate, temephos
Carzol, formetanate hydrochloride
Ciodrin, crotoxyphos
Counter, terbufos
Di-Syston, disulfoton (honey bee repellent)
Dyfonate, fonofos
Larvin, thiodicarb
Lorsban 15G, chlorpyrifos
Metasystox-R, oxydemeton-methyl
Mocap, ethoprop
Pyramat
Systox, demeton (honey bee repellent)
Thimet, phorate
Thiodan, endosulfan
Trithion, carbophenothion
Vydate, oxamyl
Zolone, phosalone

RELATIVELY NONTOXIC MATERIALS

Materials in this group can be used around bees with few precautions and a minimum of injury to bees.

Insecticides and Acaricides (trade names and common names)

Acaraben, chlorobenzilate
Bacillus thuringiensis (several trade names)
Birlane, chlorfenvinphos
Delnav, dioxathion
Dessin, dinobuton
Dimilin, diflubenzuron (insect growth regulator)
Dylox, trichlorfon
Fundal, chlordimeform
Galecron, chlordimeform
Heliothis polyhedrosis virus
Kelthane, dicofol
Marlate, methoxychlor
Morestan, oxythioquinox
Morocide, binapacryl
Murvesco, fenson
Omite, propargite
Pentac, dienochlor
Plictran, cyhexatin
pyrethrum
rotenone
Sevin XLR Plus, carbaryl
Tedion, tetradifon

Fungicides (trade names and common names)

Afugan, pyrazophos
Arasan, thiram
Benlate, benomyl
Bordeaux mixture
Bravo, chlorothalonil
captan
copper oxychloride sulfate
copper sulfate
Cyprex, dodine
Difolatan, captafol
Dithane M-45, mancozeb
Dithane Z-78, zineb
Du-Ter, triphenyltin hydroxide
Dyrene, anilazine
ferbam
glyodin
Karathane, dinocap
Kocide, copper hydroxide
Morestan, oxythioquinox
Morocide, binapacryl
Mylone, dazomet
Phaltan, folpet
Polyram, metiram
Ridomil, metalaxyl
sulfur
Vitavax, carboxin
Zerlate, ziram

Herbicides, Defoliants, and Desiccants (trade names and common names)

Aatrex, atrazine
Alachlor
Alanap, naptalam
Amiben, chloramben
amitrole
Ammate, AMS
Avenge, difenzoquat
Balan, benefin
Banvel, dicamba
Basagran, bentazon
Betanal, phenmedipham
Betanex, desmedipham
Bladex, cyanazine
Blazer, acifluorfen
cacodylic acid
Casoron, dichlobenil
2,4-D
DNBP, dinitrobutylphenyl
dichlorprop, 2,4-DP
diquat
Dual, metolachlor
Eptam, EPTC
Eradicane, EPTC + safener
Evital, norflurazon
Garlon, triclopyr
Goal, oxyfluorfen

Herbicides, Defoliants, and Dessicants (trade names and common names), continued

Hoelon, diclofop-methyl
Hyvar, bromacil
Karmex, diuron
Kerb, pronamide
Lasso, alachlor
Lorox, linuron
Maloran, chlorbromuron
MCPA
Methar, DSMA TOK, nitrofen
Milogard, propazine
Modown, bifenox
Paarlan, isopropalin
Planavin, nitralin
Pramitol, prometon
Preforan, fluorodifen
Princep, simazine
Probe, methazole
Prowl, pendimethalin
Ramrod, propachlor
Randox, CDAA
Roundup, glyphosate
Sancap, dipropetryn
Sencor, metribuzin
Sinbar, terbacil
Surflan, oryzalin
Sutan +, butylate
Telvar, monuron
Tenoran, chloroxuron
TOK, nitrogen
Tolban, profluralin
Tordon, picloram
Treflan, trifluralin
Zorial, norflurazon

Nematicides and Miscellaneous (trade names and common names)

Exhalt 800 (sticker/extender)
gibberellic acid (plant growth regulator)
Mylone, dazomet
N-Serve, nitrapyrin (nitrification inhibitor)

SOME ADDITIONAL POINTS TO REMEMBER

1. Prevention of bee losses is the joint responsibility of the spray operator, the farmer, and the beekeeper. Beekeepers should be notified in ample time before a pesticide application to allow them to protect or move their colonies. Most beekeepers cannot move their colonies before a spray application.

2. Sprays are generally less hazardous to bees than are dusts.

3. Late evening and early morning spray treatments (after 9 p.m. and before dawn) will generally reduce bee deaths. However, bees are safer when applications to corn are made between noon and midnight, *not* early in the morning.

4. Aircraft applications of technical or low-volume malathion are *highly* poisonous to bees and should be used chiefly on rangelands for grasshopper control.

5. Ground sprayer treatments usually are less hazardous to bees than are aircraft applications.

6. Spraying or dusting while bees are active in the fields will increase bee kills.

7. During hot weather when bees are clustered outside the hives, treatment over hives increases bee deaths.

8. Drift to neighboring fields in blossom, or to adjacent blossoming weeds and wild flowers, may result in substantial bee poisoning.

9. Bees located in or very near fields at the time pesticide treatments are made may sustain serious death losses. Bees moved into fields and orchards after spraying is completed may suffer little loss.

10. To eliminate pests without endangering the bees, use the recommended amount of a pesticide that is least toxic to the bees but potent enough to kill targeted pests.

11. Bees fly most actively at temperatures above 55°F. Spraying when temperatures stay below 55°F will do little harm to bees.

12. Insecticides cause heavy bee losses if applied to orchards when the clover beneath the trees is in bloom. Significant bee losses also occur when insecticides are applied to alfalfa when weeds, such as yellow rocket and mustard, are in bloom.

Table 1. Fish Toxicities (LC_{50}s) of Agricultural Insecticides Used in Illinois

Trade name	Common name	LC_{50}[a] Rainbow trout	LC_{50}[a] Bluegill	LC_{50}[a] Other	
Lorsban	chlorpyrifos	0.003	...		*Extremely toxic.* Do not use in the vicinity of streams or ponds or where drift or runoff will probably occur.
Pydrin	fenvalerate	0.0036	...		
Ambush, Pounce	permethrin	0.009	...		
Supracide	methidathion	0.01	0.0022		
Counter	terbufos	0.01	0.004		
Dyfonate	fonofos	0.02[b]	0.007[b]		
Thimet	phorate	0.013	...		
Force	tefluthrin	...	...		
Cythion	malathion	...	0.103		*Highly toxic.* Use great caution if applied in the immediate vicinity of streams and ponds.
Furadan	carbofuran	0.28	...		
Imidan	phosmet	0.50[b]	0.16[b]		
Dylox	trichlorfon	1.75[b]	3.17[b]	6.2 (carp)	*Moderately toxic.* Use cautiously around streams and ponds. Avoid direct application of the pesticide to fish-bearing ponds or streams.
Larvin	thiodicarb	2.55	1.21		
Diazinon	diazinon	2.6-3.2	16		
Penncap-M	methyl parathion	2.7	...		
Lannate, Nudrin	methomyl	3.4	0.87		
Sevin	carbaryl	...	...	5-13 (fish)	
Mocap	ethoprop	13.8	2.07		
Cygon	dimethoate	...	...	40-60 (mosquito fish)	*Least toxic.* Reasonably safe for use around fish-bearing ponds or streams.
Orthene	acephate	1,000	2,050		
Dipel	*Bacillus thuringiensis*	NT[c]	NT[c]		

[a]Concentration (parts per million, or mg/L of pesticide needed to kill 50 percent of the test fish in an aquarium during a 96-hour period. Values obtained from *The Pesticide Manual: A World Compendium*, 8th edition (1987, Lavenham Press,Ltd.), unless otherwise noted.

[b]Value obtained from W.W. Johnson and M.T. Finley (1980) *Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates* (U.S. Dept. Interior, Fish and Wildlife Service, Resource Publ. 137).

[c]NT - No evidence of acute or chronic toxicity to fish.

Rodent Damage Control in Conservation Tillage Systems

R. Corrigan
(Purdue University, West Lafayette, Indiana)

There is considerable concern among farmers who practice conservation tillage that rodents will become a more serious problem because of the increased amount of vegetation or "rodent cover" left on the surface of the soil. However, one should not assume that rodents, in general, will become significant economic pests in all fields under conservation tillage. Whether rodent populations will increase and cause economic damage in a particular cornfield depends on many conditions. The species of rodent, phase of the rodent's population cycle, reproductive condition of the rodents, past history of the field, type of edge surrounding the field, weather conditions, and several other factors all affect the potential for rodent damage.

Of the various types of conservation tillage operations, *no-till* and *cover crop operations* are probably the best candidates for damage caused by rodents. The large amounts of vegetation change the habitat structure, and the lack of tillage allows undisturbed establishment of rodent burrows. Damage occurs in these fields after herbicide applications destroy much of the food resource of the rodents, which often turn to the corn seeds and young plants as an alternate food source.

The rodents that can cause damage to corn in Illinois include:

1. deer mouse *(Peromysus maniculatus)*
2. house mouse *(Mus musculus)*
3. prairie and meadow voles (*Microtus* spp.)
4. thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)*

MICE AND VOLES

Appearance and Life History

Deer Mice and White-footed Mice. These two mice are very similar in biology and behavior, and it is very difficult for a layperson to distinguish between the two. Both deer mice and white-footed mice are small mice with large protruding eyes, long coarse whiskers, and a bicolored furry tail one-third to one-half of the animal's total length. The upper body color varies from slate gray to a golden brown. The belly area and feet are white. The total length of deer mice and white-footed mice is between 5 and 6 inches (12.7 and 15.2 cm). Both species produce an average of four litters a year containing four mice per litter. Once established in a crop area, these mice may inhabit both the open fields and brushy areas of the crop and may become abundant in corn, wheat, and soybean fields.

House Mice. The common house mouse is also found in crop fields. This mouse requires vegetative cover and is therefore more likely to be found in weedy edges and/or reduced tillage fields. The house mouse is approximately the same size as the deer mouse, but the entire body is a uniform dull gray.

Also, the tail is not bicolored and furred, but rather seminaked with only sparse hairs. House mice are capable of producing eight to ten litters per year with four to six young per litter.

Voles. Voles are easily distinguished from other small field rodents by their short tails, which are one-half of their total length, and by their short, hairy ears, which hardly project above the fur. Adult voles average about 6 inches (15.2 cm) in length and are robust-bodied with long, soft fur. Color may vary seasonally, but normally the fur is chestnut brown (head, back, and sides) and grayish brown (belly).

Voles can produce up to five or six litters per year, averaging about eight young per litter. Vole infestations in good habitat such as alfalfa will normally begin as small isolated colonies on grassy borders adjacent to crop acreage. As vole populations increase, the young adults move into the crop area. Voles will usually have a network of 1.5 inch wide (3.8 cm) runways that are connected with shallow underground burrows.

Damage

Deer mice, white-footed mice, and house mice occasionally damage corn and soybean crops when they dig up and consume the seed or nibble on the plants themselves. These mice may also become nuisances during autumn when they feed continuously on stored corn.

Voles are less of a problem pest in corn and soybean fields, but they may be more troublesome in winter wheat and alfalfa fields. Voles will feed on both the tops of alfalfa plants and the roots.

Sampling Method

To determine the presence of field mouse populations, inspect the affected area for mouse burrows and runways. Also inspect for signs of mouse activity in areas such as grassy borders adjacent to the crop, weedy ditch banks, roadside and railroad rights of way, and randomly selected spots within the field itself. *Scout field a few weeks before planting.*

Mouse burrows measure 1.5 to 2.0 inches in diameter and are easily seen. Runways are approximately 1.5 inches wide and cut through vegetation, connecting the underground burrows. If burrows and runways are abundant, control efforts should be initiated before planting.

Management Guideline

Cultural Control. Cultural practices can affect field mouse populations significantly. Clean cultivation and weed control along crop borders, fencerows, roadsides, and ditch banks are important preventative measures. These areas provide excellent mouse harborage from which wintering mouse populations can expand rapidly and emigrate to crop areas after planting.

Alternate Feeding. Although it is an untested technique, there is some evidence that suggests that alternative feeding may be effective in reducing bird and rodent damage to newly planted corn in reduced or no-tillage fields. This procedure involves scattering water-soaked grain such as corn or wheat on the soil surface at planting time. The seed can be scattered by hand or by attaching an extra planter box behind the regular corn planter.

Chemical Control. Seed repellents containing methylcarbamate used for repelling birds from corn seed are also very effective against rodents. But the availability of these repellents has been inconsistent during the past few years. Check with local agricultural chemical suppliers or crop consultants concerning the availability and current label status of these products.

As of the fall of 1989, poison baits (for example, zinc phosphide) are no longer available for rodent control in crop fields. However, this situation also may change periodically. Check with local agricultural chemical suppliers, the USDA Animal Damage Control State Office, local Extension office, or crop consultants concerning the availability of poison baits for rodent control.

GROUND SQUIRRELS

Description

The thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)*, often called a "striped gopher," derives its name from the 13 alternating light and dark stripes on its back. Adult ground squirrels are about 11 inches (28 cm) in length and have a body weight that varies between 4 ounces (113.4 g) in early spring to nearly 9 ounces (255 g) just before they hibernate in the fall. Thirteen-lined ground squirrels can be distinguished from tree squirrels by their shorter and less bushy tails and by the fact they live in the ground and are not good climbers. They most closely resemble chipmunks, but chipmunks do not have the 13 stripes and are smaller in size.

Damage

The food of ground squirrels consists of various weed and plant seeds (for example, corn seeds), insects, and leafy vegetation. When they are numerous, ground squirrels can do significant damage to corn and other crops. Ground squirrels dig up planted seeds and consume emerging sprouts. Considerable amounts of seed may be taken because ground squirrels are able to gather the seeds and store them in their cheek pouches to be carried off and buried in shallow caches or stored in their burrows. Damage to crops typically occurs in areas near fencerows, grassy borders, roadsides, etc.

Management Guideline

Ground squirrels can be controlled using traps, gases, and poison baits.

Gas cartridges used against woodchucks are also effective against ground squirrels. When ignited, these cartridges release carbon monoxide into the burrow system, killing the ground squirrel. Gas cartridges are available from local farm supply stores, some county Extension offices, and the U.S. Fish and Wildlife Service.

Gas cartridges should be used as follows:

1. Locate the burrow opening (identified by a mound of fresh excavated soil).
2. With a spade, cut a clump of sod slightly larger than each opening. Place the sod near each entrance.
3. To prepare the gas cartridge for ignition, follow the written instructions on the label.
4. Kneel at the burrow opening, light the fuse, and immediately place (do not throw) the cartridge as far down the hole as possible. Gas cartridges are not bombs and will not explode. A long stick can be used to aid in pushing the cartridge deep into the burrow.
5. Immediately after placing the cartridge in the burrow, close the main opening by covering it with the piece of precut sod, grass side down, to prevent smothering the cartridge with dirt.
6. Stand by for three to four minutes and watch burrow holes. Seal those from which smoke is escaping.
7. Repeat these steps until all burrows in and around problem areas have been treated.

Avoid prolonged breathing of gas cartridge smoke. Also, because sparks may be thrown, gas cartridges should not be used near buildings or any combustible materials.

For best results, treat burrows on cold, rainy days or during periods of inactivity on other days. Because vacant burrows may be reoccupied by ground squirrels from adjoining areas, all fumigated burrows should be rechecked weekly for one month. Any reoccupied burrows should be retreated. Do not fumigate after September because most ground squirrels will be in hibernation and the hibernating chamber is often "walled off," rendering a fumigation treatment ineffective.

Poison baits containing zinc phosphide are also effective against ground squirrels. But these baits can only be applied to noncrop areas such as fencerows, weedy noncrop borders, roadsides, etc. Baits cannot be applied where plants are grown for food or feed. Check with local ag chemical suppliers, the USDA Animal Damage Control State Office, your local Extension office, or crop consultants concerning the availability of poison baits for ground squirrel control.

Trapping is also an effective method of controlling ground squirrels, but it is only practical when there are just a few squirrels posing a problem. Either number 0 steel traps or a regular wood-base snap trap used to trap rats can be used. Traps should be placed in shallow depressions near the burrow entrances and lightly covered with dry dirt. Squirrels can be lured into the traps by sprinkling small amounts of grain on the earth covering them. Traps should be secured to prevent them from being dragged into the burrow.

Alternate Feeding. Although it is an untested technique, there is some evidence that suggests that alternative feeding may be effective in reducing bird and rodent damage to newly planted corn in reduced or no-tillage fields. This procedure involves scattering water-soaked grain such as corn or wheat on the soil surface at planting time. The seed can be scattered by hand or by attaching an extra planter box behind the regular corn planter.

CONVERSIONS

Fluid

1/6 fluid ounce (oz) = 1 teaspoon (tsp)
1/2 fluid ounce = 1 tablespoon (tbs) = 3 teaspoons
1 fluid ounce = 2 tablespoons = 1/8 cup
8 fluid ounces = 1 cup = 1/2 pint (pt)
16 fluid ounces = 2 cups = 1 pint
32 fluid ounces = 4 cups = 1 quart (qt)
128 fluid ounces = 16 cups = 1 gallon (gal)

Linear

1 inch = 2 1/2 centimeters (cm) = 25 1/2 millimeters (mm)
1 foot (ft) = 12 inches (in)
1 yard (yd) = 3 feet
1 rod = 5 1/2 yards = 16 1/2 feet
1 mile = 320 rods = 1,760 yards = 5,280 feet

Area

144 square inches = 1 square foot
9 square feet = 1 square yard
30 1/4 square yards = 1 square rod
= 272 1/4 square feet
43,560 square feet = 1 acre
4,840 square yards = 1 acre
160 square rods = 1 acre
640 acres = 1 square mile

Weight

1 ounce = 28 1/3 grams (g)
1 pound (lb) = 16 ounces = 453 1/2 grams
2 1/5 pounds = 1 kilogram (kg) = 1,000 grams
1 ton = 2,000 pounds = 907 kilograms

DILUTION TABLES

Amount of Liquid Pesticide Product Required to Obtain Recommended Rate

Concentration of liquid formulation	Recommended pesticide active ingredient (a.i.) per acre or 100 gallons of water				
	¼ lb	½ lb	1 lb	2 lb	3 lb
	Amount of pesticide product required				
1 lb/gal	1 qt	2 qt	1 gal	2 gal	3 gal
1½ lb/gal	1⅓ pt	1⅓ qt or 2⅔ pt	5⅓ pt	5⅓ qt	2 gal
2 lb/gal	1 pt	1 qt	2 qt	1 gal	6 qt
4 lb/gal	8 oz	1 pt	1 qt	2 qt	3 qt
6 lb/gal	6 oz	10 oz	1⅓ pt	1⅓ qt	2 qt
8 lb/gal	4 oz	8 oz	1 pt	1 qt	3 pt

Amount of Dry Pesticide Product Required to Obtain Recommended Rate

Concentration of dry formulation	Recommended pesticide active ingredient (a.i.) per acre or 100 gallons of water				
	¼ lb	½ lb	1 lb	2 lb	3 lb
	Amount of pesticide product required				
15%	1⅔ lb	3⅓ lb	6½ lb	13 lb	20 lb
25%	1 lb	2 lb	4 lb	8 lb	12 lb
40%	10 oz	1¼ lb	2½ lb	5 lb	7½ lb
50%	8 oz	1 lb	2 lb	4 lb	6 lb
65%	6 oz	12 oz	1½ lb	3 lb	4½ lb
75%	5⅓ oz	11 oz	1⅓ lb	2⅔ lb	4 lb
80%	5 oz	10 oz	1¼ lb	2½ lb	3¾ lb

Poison Resource Centers

The Poison Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Resource Center will give you first-aid information and direct you to local treatment centers if necessary.

Chicago and Northeast Illinois

1753 West Congress Parkway
Chicago, Illinois 60612
Telephone: 800-942-5969

Northern and Central Illinois

530 N.E. Glen Oak
Peoria, Illinois 61603
Telephone: 800-322-5330

Central and Southern Illinois

800 East Carpenter
Springfield, Illinois 62702
Telephone: 800-252-2022